SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

The JOURNAL of the FEDERATION OF SEWAGE WORKS ASSOCIATIONS

ANNUAL CONVENTION NUMBER

Special Features

Gas Engine Selection—Hayes

Dual Disposal at Jasper, Ind.—Couch and Kulin

Toxicity Review—FSWA Research Committee

Complexation of Cyanides—Milne

Twenty-Third Annual Meeting—Oct. 9–12, 1950
Hotel Statler, Washington, D. C.
(See Page 1248)

SEPTEMBER, 1950—VOL. 22, No. 9

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SWING DIFFUSERS with PRECISION TUBES

Permit continuous operation of an aeration battery without standby tanks.

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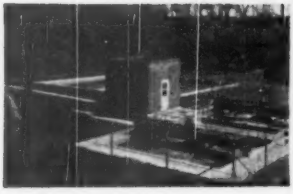

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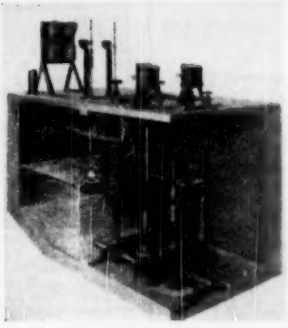

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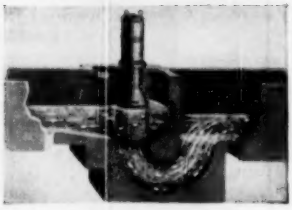

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This purification process usually requires special plant construction, and invariably the necessity exists of obtaining flow data, whether this be the simple indication of flow rate or a more permanent method of recording and totalizing the flow through the plant. With purification processes of this kind, measuring equipment usually is located at the point of discharge of partially filled pipe or in open channels, where low heads or pressures exist and where measurement is either difficult or impossible when using standard forms of measuring instruments.

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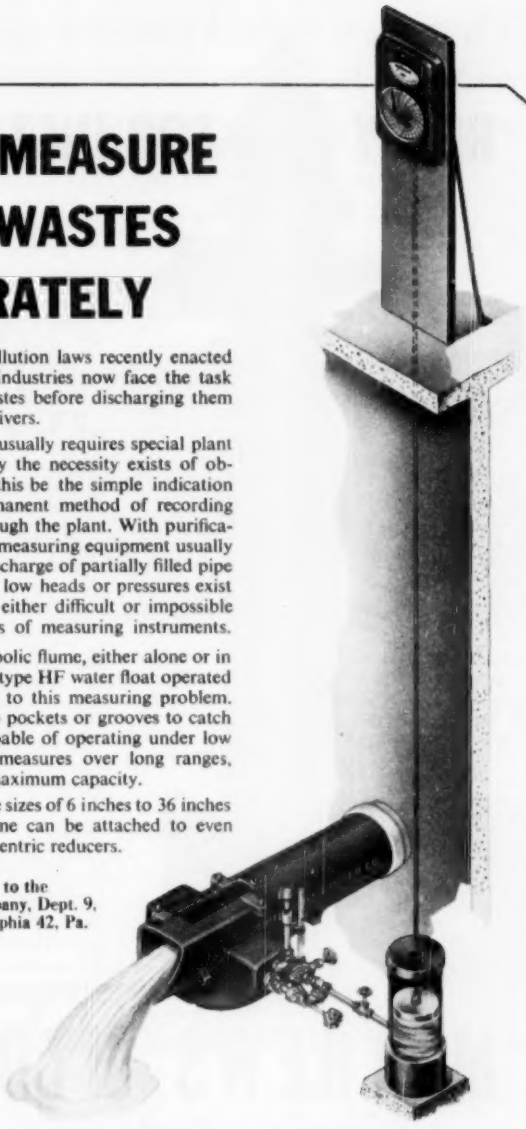

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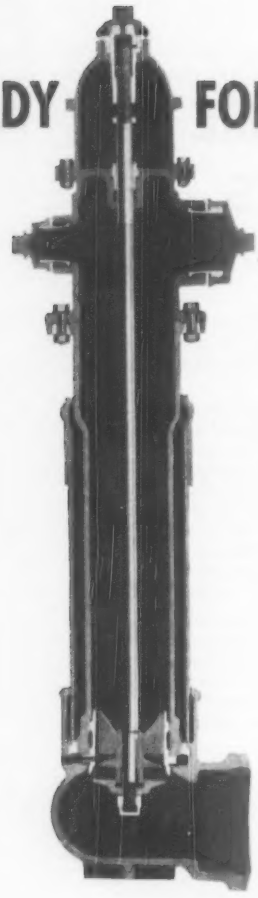

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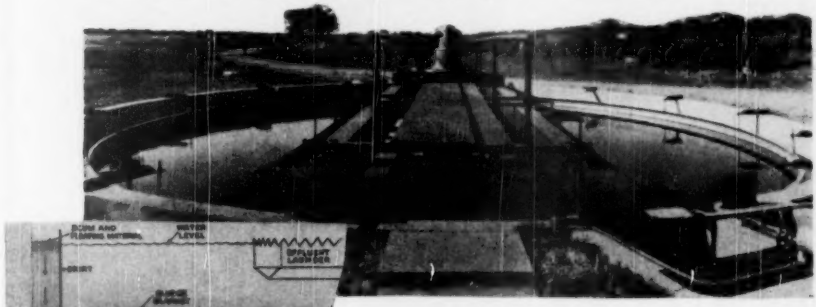

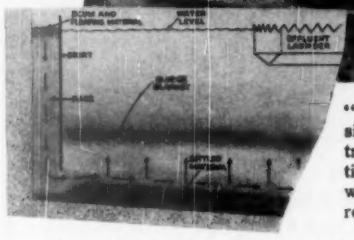

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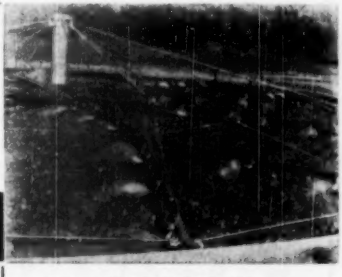

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ARMCO SEWER PIPE

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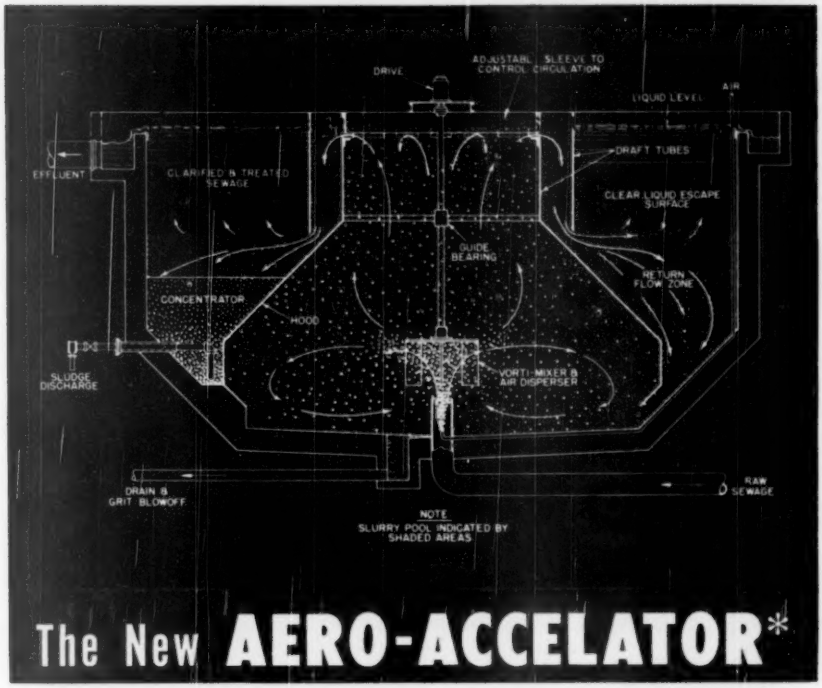

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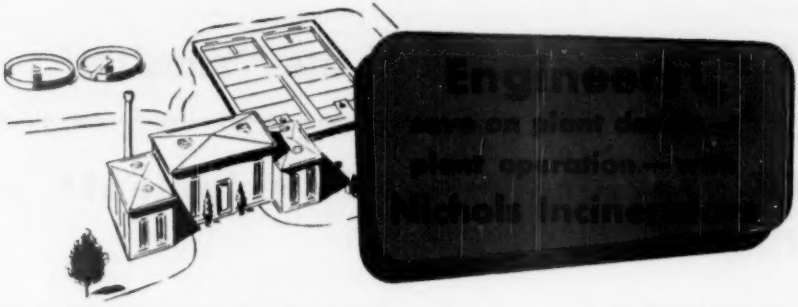

'Why is sludge incineration so important in modern sewage treatment plants?

BECAUSE . . .

★ Drying beds, digesters, unsightly, unsanitary sludge dumps are eliminated.

★ In many cases raw sludge is dewatered and incinerated without intermediate treatment.

★ Incineration provides a ready means for disposal of grit, screenings and scum.

★ Sludge produced by any basic method of sewage treatment is successfully incinerated, either digested or raw.

★ Experience shows incineration is normally cheaper than sludge hauling and dumping.

★ Positive sludge disposal is assured regardless of weather conditions.

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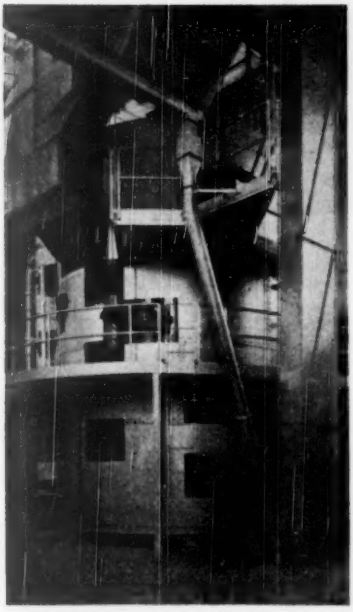

A Nichols Multiple Hearth sludge incinerator installation. Note the simplicity of design and compactness.

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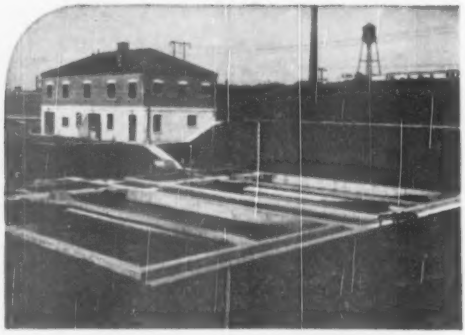
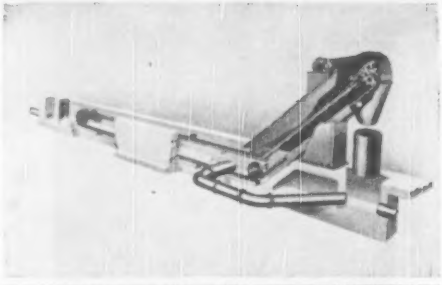
for the "BIGS" and the "smalls"

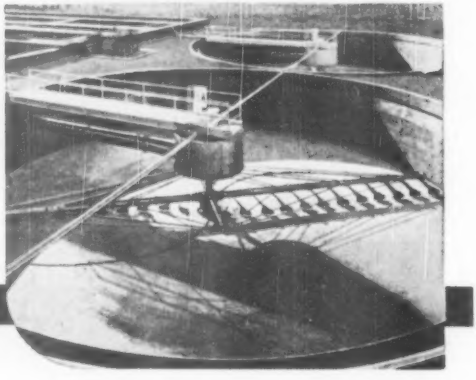
REX provides *proved* equipment!



REX CONVEYOR SLUDGE COLLECTORS combine the well-known advantages of the rectangular settling tank with a rugged and efficient form of sludge removal mechanism. Whether handling primary sludge or light flocculent solids, their performance is efficient and economical.



REX GRIT EQUIPMENT with its exclusive recirculating principle, effectively separates and removes inorganic solids from liquids. No grit washer is required. Rugged construction assures long, economical service.



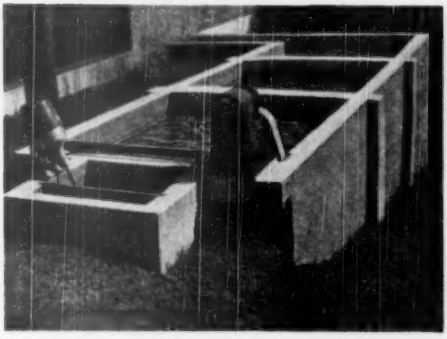
REX TOW-BRO SLUDGE COLLECTORS assure accurate control of sludge removal over a wide range of withdrawal rates through their exclusive suction principle. Sludge is removed immediately on contact instead of the usual plowing or scraping. Greater sludge concentration, greater operating flexibility, and a clearer effluent are a few of the many advantages.

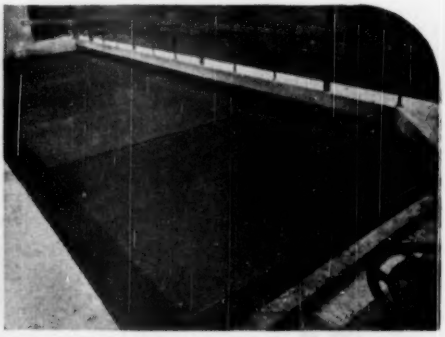
Large plant or small . . . primary or complete treatment . . . domestic or industrial waste, Rex Sanitation and Process Equipment is right for all.

Rex engineers consider the requirements of the small plant as well as the large . . . provide equipment that exactly suits the requirements. Equipment for the smaller plants is not just "scaled down" but is designed and built for the specific problems encountered. Conversely, large plant units are built for the job they must do.

Too, Rex answers the problem of the overloaded plant . . . offers equipment that can frequently expand existing capacities without enlargement of plant size.

In any plant, Rex provides unequaled efficiency . . . capacity . . . sets the standards for economical, long-life operation. Specially trained Rex sanitation engineers will be happy to assist you with your individual problems. For complete information, write for your copy of Bulletin 48-41. Chain Belt Company, 1606 West Bruce Street, Milwaukee 4, Wisconsin.

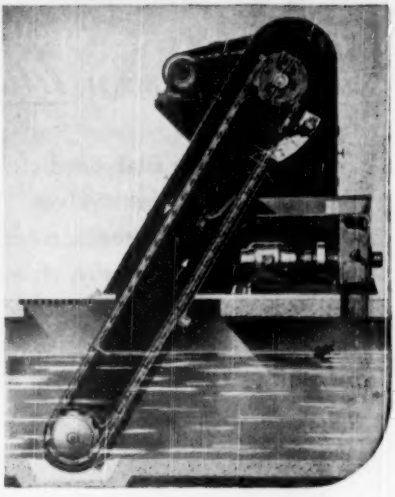




REX SLO-MIXERS AND FLASH MIXERS assure rapid disbursement of chemical throughout the liquid, followed by a gentle, multi-stage slow mixing for optimum floc formation. Rex Slo-Mixers eliminate short-circuiting and effect savings in chemicals.

REX VERTI-FLO delivers a highly clarified effluent with an extremely short detention period. It provides maximum tank capacity for any desired tank size and maximum practical weir length. The combination of large weir length and low vertical velocities assures a clearer effluent, for greater capacity at minimum cost.

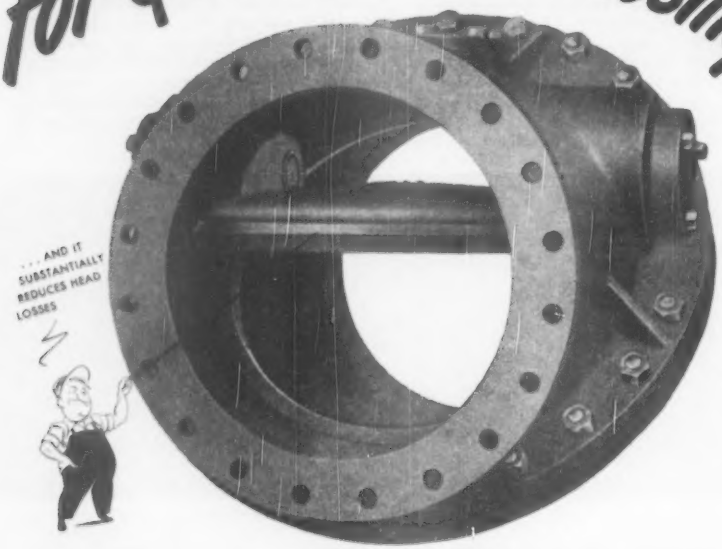
REX MECHANICALLY CLEANED BAR SCREENS AND TRITURATORS are neat, streamlined units that provide an efficient means of removing large solids from liquids and reducing them in size. Reduced material is returned into the sewage flow for quick and efficient handling in settling tanks and digesters.



CHAIN BELT REX COMPANY

SANITATION EQUIPMENT

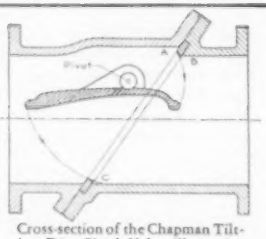
For Quick, Quiet Closing...



USE CHAPMAN *Tilting Disc* CHECK VALVES

You get truly cushioned closing with these tilting-disc check valves. There's no slamming. Instead, the disc rides smoothly on the flow, opens easily, closes quickly and quietly. Because of this effortless action, power costs are lower (when used on pump discharge lines) . . . maintenance costs are lower . . . operating expenses are saved in a dozen ways.

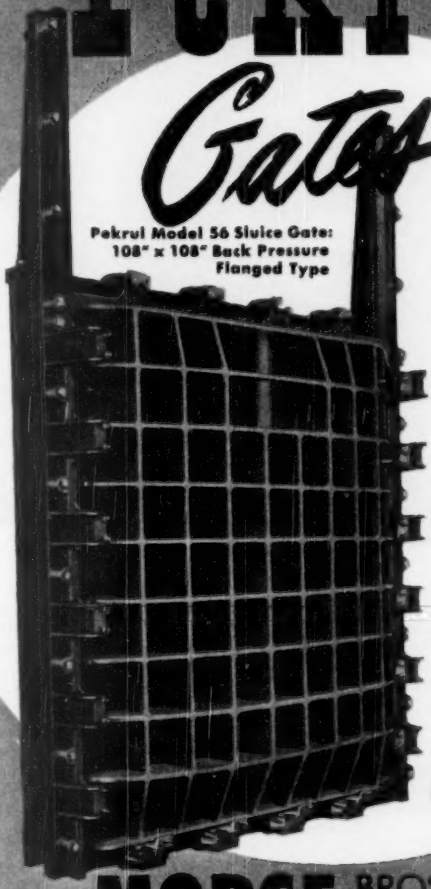
Available in either iron or steel. Write for bulletin with complete information.



Cross-section of the Chapman Tilting Disc Check Valve illustrating the way that the balanced disc is supported on the pivot, with arrows showing the travel of the disc. A feature of the design is that the disc seat lifts away from the body seat when opening, and drops into contact when closing, with no sliding or wearing of the seats.

The Chapman Valve Mfg. Co.
INDIAN ORCHARD, MASS.

Pekrul Gates



Pekrul Model 56 Sluice Gate:
108" x 108" Back Pressure
Flanged Type

MANUFACTURERS OF
PEKRUL GATES FOR:

Flood Control
Levees
Irrigation
Water Works
Dams
Sewage Disposal
Reservoirs
Pumping Plants
Oil Refineries
Fish Hatcheries
Rearing Ponds
Recreation Pools
Cooling Towers

PEKRUL GATE DIVISION

MORSE BROS. MACHINERY
DENVER, COLORADO

Write for Catalog 49

Where corrosive conditions are *toughest* apply Bitumastic Enamels!

THE integral metal parts of a sewage disposal plant, as well as the steel pipe lines leading into it, are exposed to extremely severe corrosive conditions.

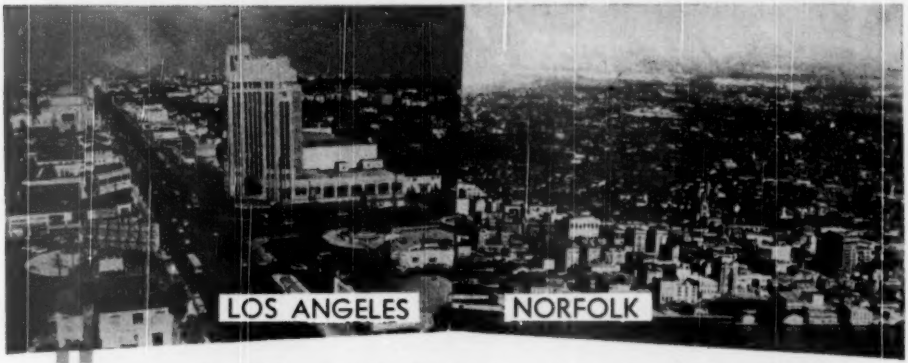
The clarifier pictured here is subjected to the highly corrosive action of sewage . . . the chemical content of industrial waste . . . the harmful effect of sewage gases and acids. Yet this clarifier, and all others in the same sewage plant, are *fully* protected against corrosion and deterioration by Koppers Bitumastic® 70-B Enamel.

Koppers Bitumastic Enamels keep water from reaching underlying metal surfaces; they provide protection against the corrosive action of chemicals; they do not deteriorate with age. And, by providing long-lasting protection, they eliminate periodic inspections.

Submit your corrosion problems for recommendations and quotations. If desired, our Contract Department will handle the job from inception to completion, furnishing special equipment, competent supervision and skilled workmen for the application work.

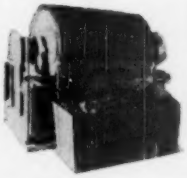
KOPPERS BITUMASTIC ENAMELS

KOPPERS COMPANY, INC., Tar Products Division, Dept. 943T, Pittsburgh 19, Pa.



Many modern progressive cities have installed or are in the process of installing equipment to give maximum protection to their citizens by dewatering sewage sludge with Eimco Continuous Vacuum, sludge dewatering equipment.

To the engineer, Eimco equipment provides a definite means of figuring the job on a predetermined dewatering basis as weather and other unpredictable features are eliminated.



To the city, Eimco equipment offers a definite saving as the engineer is able to make his digestors or sludge storage tanks smaller when dewatering can proceed at a definite rate. Maintenance should be less on vacuum filters than on sludge beds when, over the years, man hours and materials are considered.

Eimco vacuum filters are engineered especially for each sewage job. The many factors entering into the Sanitary Engineers survey are factors in which we, as manufacturers, are also interested in order to assure a satisfactory filter installation. Many installations including Summer & Winter resorts, industrial plants, plants treating industrial wastes exclusively and other cities where domestic and industrial wastes are combined are all successfully using Eimco equipment — in many cases Eimco equipment working side by side with other equipment is doing a superior job.

Your inquiry is invited.

Cities using Eimco sludge dewatering Equipment include: City of East Chicago, Ind.; City of Baltimore, Md.; City of Great Neck, L. I., N. Y.; City of Cranston, R. I.; City of Tonawanda, N. Y.; City of Birmingham, Mich.; City of Snoqualmie, Wash; City of Belgrave, L. I., N. Y.; City of Piqua, Ohio; City of Anderson, Ind.; City of Wausau, Wis.; City of Stamford, Conn.; and many others.

EIMCO

THE EIMCO CORPORATION

A195

...NOW REDESIGNED FOR STILL HIGHER EFFICIENCY

If you're pumping solids ... not large enough to require regular non-clog slow speed sewage pumps ... you'll find Economy volute mixed flow pumps the answer to your problem. Engineered for greater economy in operation, the Economy mixed flow volute line, tested and proved in twenty-two years of operation, has now been redesigned for still higher efficiency.

Built to keep pumping longer at lower cost these pumps are equipped with the highest duty bearings available, including double row, angular contact thrust bearing. Large size pumps also have a self-aligning, spherical roller radial bearing.

Capacities range from 3,000 to 50,000 G.P.M., heads from 10 to 50 ft. For complete details, write Dept. AC-9.

Centrifugal, axial and mixed flow pumps for all applications.

Economy Pumps Inc.

DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

FOR SEWAGE, WASTE AND WATER TREATMENT

IMPINGEMENT AERATOR

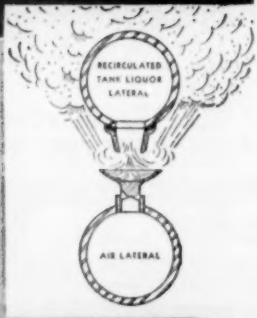
DIFFUSAIR

PRE-AERATION...ACTIVATED SLUDGE...CARBONATION

The principle involved consists of a water jet, impinging on a hydraulic bowl placed over an air stream. This causes physical contact and shearing between the two masses at the bowl periphery. The Impingement Aerator DIFFUSAIR produces smaller bubbles than any other known form of air diffusing. Write for Bulletin 17531.

PROVEN BETTER 5 WAYS

1 Less than 2 lbs. of Impingement Water Pressure Required.
2 High Oxygen Absorption — Air Requirement Reduced.
3 Oxygenation Rate Adjustable Over A Wide Range.
4 No Pores To Become Clogged.
5 No Air Filters Required.



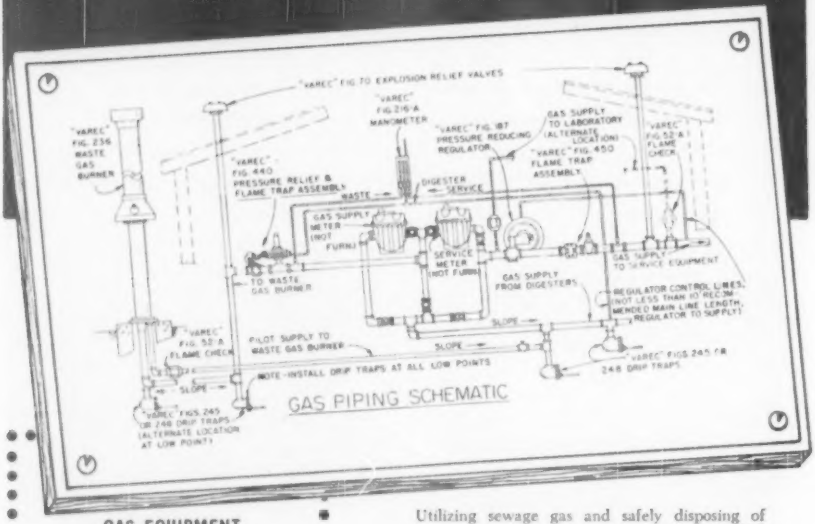
WALKER PROCESS EQUIPMENT INC.

FACTORY • ENGINEERING OFFICES • LABORATORIES

518 HANKES AVENUE, AURORA, ILLINOIS

PROQUIP

"VAREC" figures in *Your* SEWAGE TREATMENT PLANT DESIGN for SAFETY and GAS CONTROL


"VAREC" FIG 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
DIGESTER SERVICE
WASTE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES (NOT LESS THAN 10' RECOM. MENDED MAIN LINE LENGTH REGULATOR TO SUPPLY)
TO WASTE GAS BURNER
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

PROVED and APPROVED "Varec"

Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

Flame flashback to valuable equipment is prevented with "VAREC" Flame Traps and Flame Checks. The flame arresting element of the Flame Trap is designed to eliminate flame propagation of even more inflammable gases than encountered in sewage service. This element is the same as that used in "VAREC" Flame Arresters listed by the UNDERWRITERS' LABORATORIES for petroleum product storage.

Emergency explosion relief is accomplished with "VAREC" Explosion Relief Valves. These valves should be installed outside of any buildings.

An enlarged engineering drawing of the above gas piping detail will be sent upon request. If you design sewage treatment plants, write today.

THE VAPOR RECOVERY SYSTEMS CO.
COMPTON, CALIFORNIA, U. S. A.
Cable Address: VAREC COMPTON USA (All Codes)
New York • Boston • Pittsburgh • Chicago • Detroit • St. Louis • Houston
Tulsa • Casper, Wyo. • Provo, Utah • Los Angeles • San Francisco • Seattle

Available from authorized Sewage Equipment agents throughout United States and Canada

Ideal for small communities, isolated institutions, outlying plants

YEOMANS SEWAGE TREATMENT PLANTS

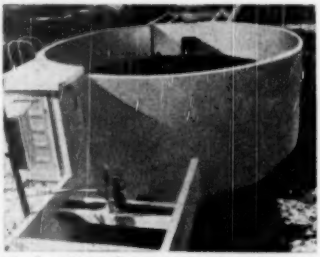
—Activated Sludge Process
or Biological Trickling Filter

THE "PACKAGE" AERIFIER

Many small communities and outlying institutions, compelled to purify wastes but lacking an ample supply of diluting water, have found in the Yeomans "Package" Aerifier an ideal answer to a critical problem.

Compact, exceedingly efficient in purification, unique for low construction and operation costs, this activated sludge plant provides aeration and final sedimentation in a single concrete unit. Operation is as simple as possible, with supervision limited to routine check-up. Every installation includes final adjustment, initial tested operation, thorough training of operators and continuing counsel from Yeomans engineers.

"WATER-WHEEL" DISTRIBUTOR



Operating in conjunction with a primary sedimentation tank, the Yeomans "Water-Wheel" Distributor applies settled sewage to a trickling filter—with unfailing dependability. Sewage flows into the rotating trough, and is spread evenly on the filter bed through V-notches and spreader plates. The trough is actuated by a water-wheel and bevel gearing. Filter beds range from 5-foot to 25-foot diameters; and the entire area is effective for treatment. Continuous positive distribution is assured at all rates of flow—which does away with the need for dosing chambers and siphons. There is none of the clogging and cleaning of spray nozzles often required with reaction distributors; and elimination of accessories saves as much as the entire cost of the complete Water-Wheel installation. Maintenance is extremely simple. Numerous Water-Wheel plants—small communities, hospitals, airports, industrial plants—provide impressive proof of this unit's extraordinary efficiency.

Helpful engineering data on these Yeomans plants will be sent promptly upon request—no obligation.

YEOMANS

PUMPS FOR BUILDINGS, MUNICIPALITIES, INDUSTRIAL APPLICATIONS—
and a complete line of Sewage and Waste Treatment Equipment

Yeomans Brothers Company
1411 N. Dayton St., Chicago 22, Illinois

Please send information as follows:

☐ Yeomans "Water-Wheel" Distributor

☐ Yeomans "Package" Aerifier

Name .....

Address .....

City ..... State .....

"Boy! Was that Commissioner impressed!"

"Said he didn't think it was possible to raise a gate so easy. Seems that in his town's plant they're forever having trouble with gates sticking and stems breaking.

"No wonder. On some of his gates there's forty tons' pressure pushing a rusty gate against rusty facing strips.

"I told him our Everdur* equipment won't stick because it never rusts. When he said they can't afford to use Everdur, I told him he can't afford *not* to.

"Proved it, too! Showed him that the little extra it cost was only a fraction of what they were spending on replacements.

"The Commissioner said he guessed I was right.

"Smart man, that Commissioner." 6817LA

*Reg. U. S. Pat. Off.

Corrosion is the enemy you can lick by fabricating your equipment with Everdur... Anaconda's Copper-Silicon Alloys. Everdur combines the corrosion resistance of copper with high tensile strength. It's available in most wrought commercial shapes; also in casting ingots. It is easy to weld and easy to fabricate.

May we send you more information on Everdur? Do you have a problem on which we can give you technical counsel? Just write to The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

Where corrosion resistance counts—use Everdur...

ANACONDA COPPER-SILICON ALLOYS

Bulletin on
POROUS MEDIA
by CARBORUNDUM
TRADE MARK

Bulletin No. 11 SEPTEMBER, 1950

Air Diffusion Also Proves Versatile Tool for Treatment of Industrial Wastes

Aeration—well recognized as an effective means of treating sewage—is also equally effective in treating almost any type of industrial waste. It is extremely versatile and can be used in one or more of the processing steps.

Whatever the objective – whether it is for "sweeping," flocculation, solids classification, or purely for oxygenation—aeration has many advantages. (Even a combination of such objectives is very practical and can be economically accomplished in the same or adjacent units.)

The most efficient aeration is done by means of the air diffusion method. And by far the best medium for air diffusion is a porous ceramic diffuser. This combination makes it possible to accurately control a uniform diffusion of small air bubbles—hence assuring optimum results in any given process.

Ceramic diffusers, such as ALOXITE aluminum oxide plates and tubes, have proved their superior efficiency through many years of use. They are rugged, uniform, chemically stable and, when operated normally, will retain their original permeability for years.

POROUS DIFFUSER BUBBLES . . .

Among the successful applications for "Aloxite" diffusers in sewage and industrial waste treatment are the following:

- Grit Separation Tanks
- Pre-Aeration—Grease Separation
- Pre-Aeration—Solids Flocculation
- Channel Aeration—Solids Suspension & Distribution
- Plain Aeration
- Step Aeration
- Tapered Aeration
- Standard Activated Sludge
- Trickling Filter Pre-Aeration
- Trickling Filter Post-Aeration
- Digestor Sludge and Liquor Nitrification
- Oxygenation of De-Inking Wastes
- Oxygenation of Tannery Waste
- Wool Scouring Waste—Degreasing
- Wool Scouring Waste—Oxygenation
- Oxygenation of Bleachery Waste

LATEST POROUS MEDIA DATA

Technicians in all fields of filtration and diffusion will find this new bulletin the most complete reference source available. Its 56 pages include many charts, tables and photographs. It covers applications, design, specifications, installation and operation. No obligation, of course.

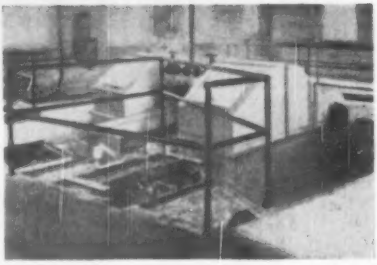
Dept. N-90
THE CARBORUNDUM COMPANY
Refractories Division
PERTH AMBOY, NEW JERSEY

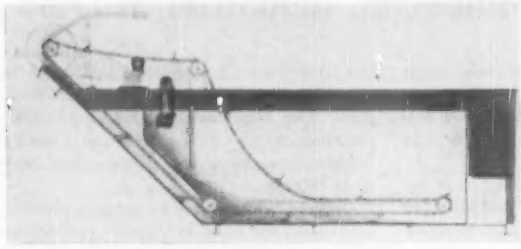
"Carborundum" and "Aloxite" are registered trademarks which indicate manufacture by The Carborundum Company.

Let Link-Belt Help You Dispose of *Industrial Wastes*

Safeguard public health or salvage valuable by-products from waste water, or perhaps do both, by means of Link-Belt equipment for water, sewage and industrial waste treatment. Note the four typical applications here shown.

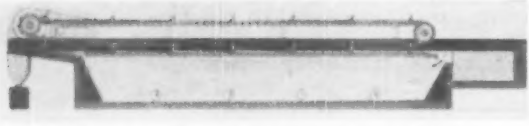
Link-Belt engineers, with a broad line of equipment and extensive experience, can aid you in planning and installing the right type of plant to solve your specific waste problems.





Above: Waste recovery system at large glue factory, consisting of enclosed revolving screens with settling pit and dewatering screw conveyor for the screenings.

Left: Coolant clarifying system utilizing Link-Belt dewatering conveyor. After clarification, coolant may be filtered or returned direct to grinding machines.



Left: Paper stock is recovered in the Link-Belt Save-All by a mechanical skimmer which collects the floating stock with a minimum of water.

Left: Heavy grit and detritus is removed from flume water at sugar beet factories, by settling in a tank equipped with a Link-Belt grit collector.

The Link-Belt line includes screens, sludge collectors, grit collectors, grit washers, chemical mixers, sludge dryers, power transmitting, elevating and conveying machinery.

LINK-BELT COMPANY

Philadelphia 40, Chicago 9, Indianapolis 6, Atlanta, Houston 1, Minneapolis 1, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8
Offices in Principal Cities

LINK-BELT

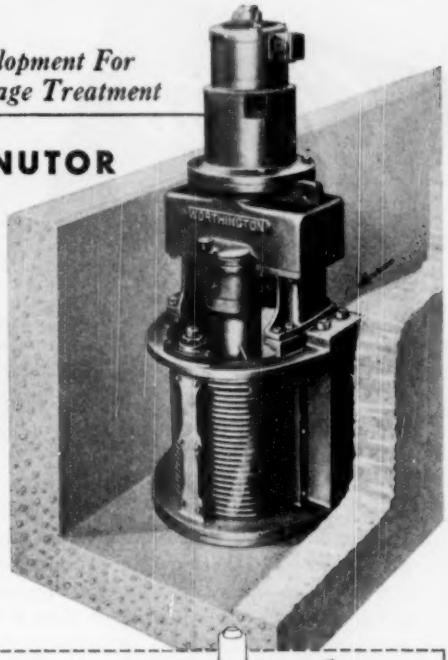
Sanitary Engineering Equipment

SEE OUR EXHIBIT—F.S.W.A. CONVENTION—
WASHINGTON, D.C.—OCTOBER 9-12

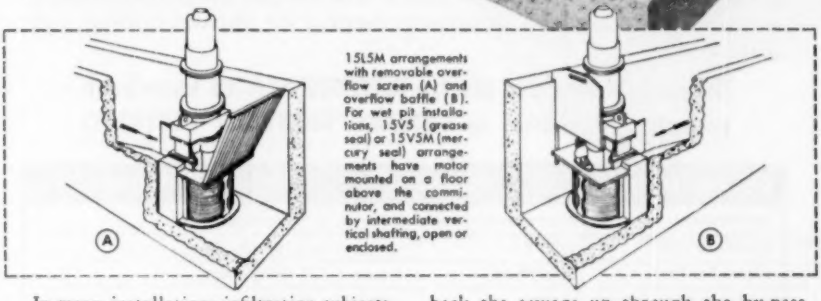
Another Worthington Development For Time- and Labor-Saving Sewage Treatment

THE ONLY COMMINUTOR WITH ALL THESE ADVANTAGES...

- **Easy installation in straight-flow rectangular sewage channels, new or old.**
- **Cutter racks quickly removable for sharpening or replacement, eliminating tedious individual cutter sharpening and adjusting.**
- **Provision for a mercury seal, for automatic protection of internal parts at unusually deep submergences. (Grease seal furnished as standard equipment.)**
- **Provision for overflow screen or baffle by means of a supporting flange.**



The 15C5 Worthington comminutor arrangement for continuous, automatic sewage solids cutting. This unit is designed for a .3 to 2.3 mgd flow range in a channel of 3 feet maximum depth. Standard grease seal supplied is suitable for water depths up to 22 inches. ➔



15L5M arrangements with removable overflow screen (A) and overflow baffle (B). For wet pit installations, 15V5 (grease seal) or 15V5M (mercury seal) arrangements have motor mounted on a floor above the comminutor, and connected by intermediate vertical shafting, open or enclosed.

In many installations infiltration subjects comminutors to peak flows and submergences beyond their maximum capacities. Only Worthington comminutors can be supplied with both a mercury seal and an overflow screen or baffle to handle this problem.

The mercury seal automatically protects the unit's internal parts up to a reasonable submergence. The gear head motor is mounted on a motor base extension pipe above high water level; channel depth may be over 3 feet. The removable overflow screen provides screening at the comminutor's overflow without causing troublesome upstream conditions, and occasional accumulations may be raked down into the unit. Or, an overflow baffle may be used to back the sewage up through the by-pass screen, preventing overflow.

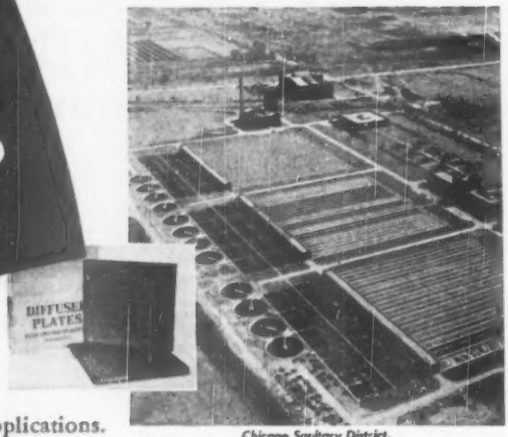
MANY OTHER ADVANTAGES

of the Worthington comminutor combine for rapid, continuous, automatic comminution — and for the long, trouble-free service life that proves *there's more worth in Worthington*. Write for bulletin W-2010-B3, and for drawings of arrangements best suited to your own application. Or contact our nearest District Office. *Worthington Pump and Machinery Corporation, Harrison, N. J.*

WORTHINGTON

W-4-1

Electro POROUS MEDIA



Chicago Sanitary District.
Electro Diffuser Plate.

For some years "Electro" has produced DIFFUSER PLATES for all diffusion applications. Two general types are supplied: Electro "Kellundite" and "Electroflo." The table below contains all the quick, essential facts of these quality produced Electro Porous Media.

A complete air conditioned testing room is provided for checking the permeability of every plate. Each plate is then stamped with its permeability rating so that plates may be suitably installed for efficient, uniform tank aeration.

Several Carloads of Electro DIFFUSER PLATES have been recently furnished to CHICAGO SANITARY DISTRICT.

CHARACTERISTICS	KELLUNDITE	ELECTROFLO
COMPOSITION	Fused Aluminum Oxide	Aluminum Silicate
STANDARD SIZE	12 x 12 x 1"	12 x 12 x 1¼"*
PERMEABILITY**	Up to 80 cfm	Up to 80 cfm
PERMEABILITY TOLERANCE	±10%	±10%
WARPAGE	Less than 1/32"	Less than 1/32"
RESISTANCE TO CHEMICAL ATTACK	Essentially unattacked by water and weak acids. Attacked by strong alkalies.	Essentially unattacked by water and weak acids. Attacked by strong alkalies.
STRENGTH	Will support a load of 1000 lbs. applied on center line.	Will support a load of 1000 lbs. applied on center line.
UNIFORMITY	Even distribution of fine bubbles over entire surface.	Even distribution of fine bubbles over entire surface.

*Thickness of 1½" required when permeability is 50 or over.
**Permeability rating is defined as the quantity of free air passed thru the 12" x 12" surface at 2" water pressure at 70° F., R. H. 15-25%.

MAY WE SEND YOU "Electro" BULLETIN 950?

Electro Refractories & Alloys Corporation
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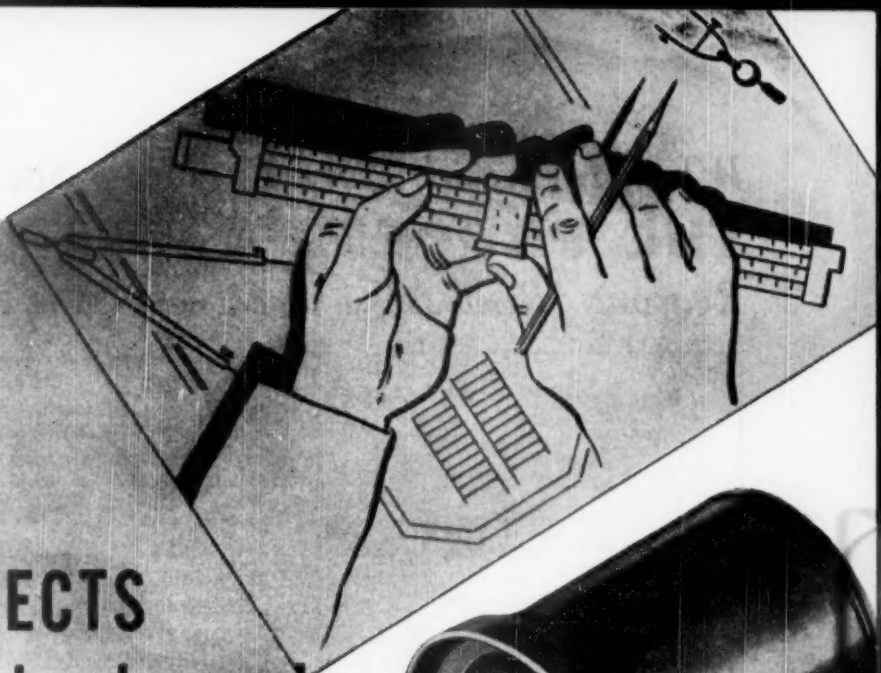
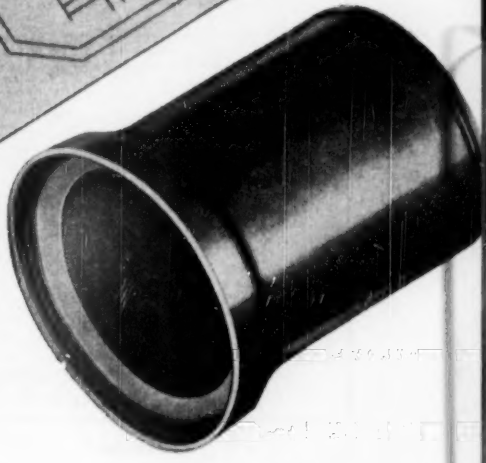


CLAY PIPE PROTECTS 'decision buyers'



WHERE products are "decision-bought" — by engineers, consultants, or men in public life — professional reputations are constantly at stake. The choice of Vitrified Clay Pipe protects those reputations, because Clay Pipe *never wears out.* It can be specified with safety on *every* sewerage or drainage job . . . for present or future wastes, for the soil conditions of tomorrow or fifty years from now. "Bad guesses" are impossible with Vitrified Clay Pipe. You can disregard sulphide controls and the effects of sewage temperature, velocities, and age of sewage, because Clay is immune to chemical action. It's the only pipe that's *sure* to protect *your* decisions . . . by lasting forever!

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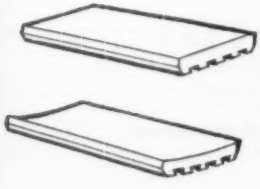
CLAY PIPE NEVER WEARS OUT!



LINER PLATES

STANDARD-STRENGTH CLAY PIPE

CLAY PIPE FITTINGS

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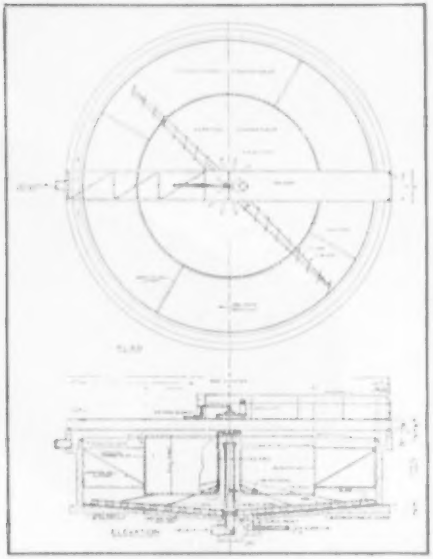
Why More and More Engineers Specify

THE PROCESS OXIDATOR

Reason: "Removal of suspended solids 75% to 85%"



TYPE BA

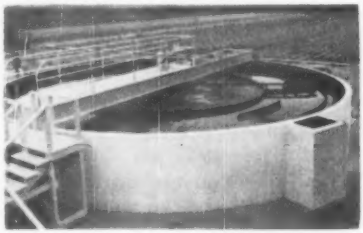
Description: The Process Oxidator combines aeration, coagulation and sedimentation in a single circular tank for the removal of suspended matter from liquids. The influent enters upward through a center column, discharges into an inner circular compartment for aeration and circulation with previously formed flocs and then passes to an outer annular compartment for upflow sedimentation. Settled solids are raked to a central sludge outlet while effluent overflows a peripheral weir. The Oxidator is flexible, permitting long or short aeration periods, gentle or intense aeration. The volume of sludge recirculated is adjustable to the incoming flow. Improved economical clarification is achieved by concentrating solids in an aerobic environment conducive to the flocculation necessary to remove colloidal and gelatinous suspended matter.

Yes—in sewage treatment the average single-stage Oxidator removes 50% more suspended solids than the ordinary clarifier *and* at only a 10% average increase in total plant installation costs!

This results in

- **IMPROVED CLARIFICATION**
- **INCREASED GREASE REMOVAL**
- **MINIMUM SCUM HANDLING**
- **GREATER REDUCTION IN BIOLOGICAL OXYGEN DEMAND**
- **REDUCED LOADING TO BIOLOGICAL FILTERS, THEREBY REDUCING SIZE AND COST**

Sizes: Process Oxidators are now in operation ranging from 15′ in diameter to 115′ in diameter. Recommended overflow rates based on gross tank area: 0.75 gpm per square foot at maximum influent rate. Below is pictured the 40 ft. dia. Primary Oxidator of the Hemet, California, sewage treatment plant.



Send for Bulletin 106 for information about this new development in sewage treatment that will mean lower initial expenditures and higher removals at greatly reduced cost per ppm removed. If you have a particular problem, contact one of the offices below and a specialized engineer will be glad to be of service to you.

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EASTERN AND MIDDLE WESTERN REPRESENTATIVE:
PACIFIC FLUSH-TANK COMPANY · 4241 RAVENSWOOD AVE., CHICAGO 13, ILL.

This new publication describing meters for sewage, industrial wastes, sludge and irrigation water should be part of your file on flow measurement. Ask for Bulletin 62.

FEATURES of BAILEY OPEN CHANNEL METERS

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3. Easy to Maintain
4. Retain Accuracy
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6. Adjustable Capacities
7. Indicate, Record and Integrate
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MU21

BAILEY METER COMPANY

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Meters and Controls for Sewage and Water

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

Without bursting strength—or, for that matter—without all of the strength factors listed opposite—no pipe laid 100 years ago in city streets would be in service today. But, in spite of the evolution of traffic from horse-drawn vehicles to heavy trucks and buses—and today's vast complexity of subway and underground utility services—cast iron gas and water mains, laid over a century ago, are serving in the streets of more than 30 cities in the United States and Canada. Such service records prove that cast iron pipe combines all the strength factors of long life with ample margins of safety. No pipe that is provably deficient in any of these strength factors should ever be laid in city streets. Cast Iron Pipe Research Association, Thos. F. Wolfe, Engineer, 122 So. Michigan Ave., Chicago 3.

Strength factors of Long Life!

No pipe that is provably deficient in any of these strength factors should ever be laid in city streets

BURSTING STRENGTH — In full length bursting tests standard 6-inch cast iron pipe withstands more than 2100 lbs. per square inch internal hydrostatic pressure, which proves ample ability to resist water-hammer or unusual working pressures.

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CAST IRON PIPE SERVES FOR CENTURIES

SEWAGE AND INDUSTRIAL WASTES

The Journal of the Federation of Sewage Works Associations

Volume 22 **SEPTEMBER, 1950** **Number 9**

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Interested in BIG SCALE sludge digestion?

Aerial view of Los Angeles Hyperion Sewage Treatment Plant. The twelve Dorr Primary Digesters are at right center with the Secondaries at left. Insert—Closeup of one of the Dorr Primary Digesters at Hyperion.

HERE are two examples of recent Dorr Multdigestion installations . . . built for big capacity . . . at a reasonable installed and operating cost:

For the 245 MGD Los Angeles Hyperion Plant

. . . 18 Dorr Digesters, each 110'—11" in diameter have recently been placed in operation. The 12 Primaries are each equipped with three draft tubes and high capacity mixers . . . the six Secondaries provide for quiescent settling.

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Dorr Multdigestion . . . providing thorough mixing of raw and digested sludge . . . is the ideal answer to big scale digestion problems. If you don't already have Bulletin #6261, write for a copy today. It contains 60 pages of detailed information on all types of Dorr Digesters.

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Sewage Works

SEWER RENTAL FINANCING IN A LARGE AND A SMALL COMMUNITY *

I. BUFFALO, NEW YORK

By John J. Joyce

Executive Secretary, Buffalo Sewer Authority, Buffalo, N. Y.

Two basic documents defined and established the necessity for, and served as the guide to the Buffalo (N. Y.) Sewer Authority in determining the form and application of sewer rents. These were the Legislative authorization and the bond agreement commitment.

The act of the State Legislature creating the Authority provides, in part:

"The Authority is authorized to establish a schedule of rates, rentals or charges to be called 'Sewer Rents,' to be collected from all real property served by its facilities, and to prescribe the manner in which and the time at which such sewer rents are to be paid, and to change such schedule from time to time as may be deemed advisable. Such sewer rents may be based upon either the consumption of water on premises connected with such facilities, making due allowance for commercial use of water, the number and kind of plumbing fixtures connected with such facilities, or the number of persons served by such facilities, or may be determined by the authority on any other equitable basis."

All bond agreements covenant that the Buffalo Sewer Authority ". . . will establish, levy, maintain and collect such sewer rents and charges as may be necessary, and such rents and charges shall be at least sufficient after making due allowance for contingencies and for a margin of error in the estimates, to provide funds to pay all operating expenses, maintenance, principal, interests and reserves on all outstanding bonds, and all other obligations." The bonds covered by these agreements are all revenue bonds, comprising the $8,365,000 prior lien for the construction of the original project, consisting of the main intercepting sewers, disposal plant, and sewerage system; and the second, or subordinate, $4,500,000 issues for storm-water relief.

Dual Basis for Charges

The engineering firm of Greeley and Hansen was employed by the Authority to study and report upon various methods of levying sewer rents in the City of Buffalo. Many proposals were examined and the Board of the Authority devoted a great deal of time to the subject, finally accepting the proposal determined to be the most equitable and the most practicable of application. This scheme provides generally for revenue divided into two principal parts or classes—sewer rent based on water use, and sewer rent based on assessed valuation of taxable real estate. This divisioning, although not generally applied in those communities charging for sewerage and disposal facilities, was thought to have particular application in the City of Buffalo, which is served for the most part by a combined system taking domestic sew-

* Presented at 1950 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Jamestown, N. Y.; June 12, 1950.

age, industrial wastes, and storm water to the extent of three and four times the dry weather flow.

Much has been said and written concerning this two-part theory of rental application. In brief, the basic thought leading to acceptance of the principle that a part of the charge could and should be applied to taxable real estate is contained in a 1938 report by the consulting engineers as follows:

"Two items in the service to be performed by the collecting sewers, the intercepting sewers and the treatment plant, are of general benefit or of general concern and may, therefore, be considered as chargeable to the general fund. These are as follows:

(a) That part of the total annual revenue which is required on account of storm water.

(b) That part of the total annual revenue which is required to provide capacity for future growth and thus to add security to vacant property."

This report, which develops the theory in detail, concludes by computing the amount chargeable each year to the general fund for handling storm water, together with the proportion of fixed charges on long-lived structures, to be approximately 45 per cent of the then annual revenue requirement of $1,500,000.

Thus, the Buffalo Sewer Authority, in fixing upon the most equitable method of raising money to pay for building and operating the new sewerage and disposal system, decided that it would be unfair to put the entire burden on water users and equally unfair to put the entire burden on real estate owners. It was decided to divide the total annual revenue required on a calculable basis—owners of taxable real estate to bear approximately 45 per cent and users of water approximately 55 per cent—with the two combined revenues producing the major part of the annual budget requirement for payment of bond principal and interest, and reserves, operation, maintenance, and repair of the sewerage and disposal system.

Where taxpayers are sufficiently informed, they are reasonable in their decisions. Interested citizens, representatives of business associations, and taxpayers' groups were invited to participate in discussion, so that when the first "schedule of sewer rents" was tentatively adopted, publicly advertised, and a final hearing held, the only formal objections that had been filed were on behalf of railroads and other industrial users of large quantities of water, who were primarily interested in being assured that water used and not returned to the facilities of the Authority would be exempted from sewer rent charges.

These objectors and other representatives and owners of large property holdings, both improved and unimproved, appeared to be satisfied with the equity and fairness of the divided or two-part sewer rent, and it is worthy of note that in the 12 years since adoption of the method no objection has been filed.

Schedule of Sewer Rents

The "Schedule of Sewer Rents," comprehensive in scope, is divided into four sections dealing, respectively, with sewer rents for premises situated within the city limits, sewer rents for premises situated outside the city limits, general provisions applicable to both classes of property, and liens of sewer rent. Highlights of the various provisions are as follows:

1. Sewer rents for premises within city limits—For the fiscal year ending June 30, 1950, the sum of $857,000 is spread over all taxable property on the city's annual assessment rolls (total $930,953,050), producing a rate of $0.92056 per $1,000 of valuation.

Users of water on metered accounts, of which there are approximately 18,500, are charged 45¢ per 1,000 cu. ft. for the first 9,000; 31.5¢ per 1,000

cu. ft for the next 9,000; and 18¢ per 1,000 cu. ft. for all over 18,000. The minimum charge is 90¢ per quarter year. This source produces an annual revenue of approximately $462,000.

Users of water on unmetered (so-called "flat rate") accounts, of which there are approximately 80,000, are charged at the rate of 45 per cent of the water bill for the premises. This source produces an annual revenue of approximately $451,500.

2. Sewer rents for premises outside city limits—A charge of $1.85 is made for each $1,000 of assessed valuation, rating the value of the property in accordance with equalization rates established by the Erie County Board of Equalization. It will be noted that this charge is approximately double that on city property. This source produces an annual revenue of approximately $4,000.

All users of water are required to be metered, and the used amount charged for in steps of 9,000 cu. ft., as in the city. However, the rate is twice that for city property, being 90¢, 63¢, and 36¢, with a quarter-year minimum of $1.80, except if water is obtained from the Division of Water of the City of Buffalo, in which case the rate is 45 per cent of the charge therefor. This source produces an annual revenue of approximately $8,000.

3. General provisions—Clauses in the over-all schedule applicable to premises both inside and outside the city limit provide for:

(a) The usual institutional rate of 1.8¢ per 1,000 gal. for asylums, churches, public hospitals, charitable institutions, schools, colleges, etc. This amounts to 13.5¢ per 1,000 cu. ft. (The origin of the gallonage basis, as provided in the city water ordinance, is a mystery. It was probably meant to give the impression that the rate of charge being granted was even more favorable than it really is!)

(b) No part of the sewer rental to be based on the charge for water used for lawn sprinkling and automatic sprinkling systems, rock gardens, and other uses of water in substantial quantities not returned to the sewerage system of the Buffalo Sewer Authority.

(c) Sewer charge or rental, in the case of large water users, to be based on the quantity of water actually entering the sewerage system, as determined by suitable metering of water usage or discharge.

(d) Special rates of charge for industrial wastes containing high concentrations or any substances adding to the operating costs of the sewage treatment works.

4. Lien of sewer rent—From and after the due date, the sewer rent constitutes a lien upon the real property served by the facilities. Such lien has the same priority and superiority as the lien of the general tax of the city.

Method of Billing

That part of the sewer rent based on assessed valuation of property is a separate and distinct bill, covering a fiscal year, and is folded in with and accompanies the city tax bill for each parcel. The City Department of Assessment prepares these 120,000 bills for the Authority at a contract cost of $1,000, mechanically imprinting the name of the owner and the description of property on each bill and stub, resulting in neat, accurate, and uniform bills. The International Business Machines Corporation then, at a contract cost of $1,050, spreads the individual sewer rents on the bills, stubs, and roll books. Sewer rents on equalized assessed valuation to "outside" users are billed directly from the Authority's office.

That part of the sewer rent based on water use is billed as a separate and distinct item on each water bill by mechanical systems installed for the joint benefit of the City Division of Water and the Authority. Sewer rents based on water use to "outside" accounts are billed directly by the Au-

thority, through the City Division of Water, and are based upon meter readings furnished by the Western New York Water Company.

Collections

Collections have been uniformly excellent throughout the years, averaging better than 96 per cent. This high collection percentage is attributable to the City Department of the Treasury and the City Division of Water policy of discouraging separate payments; enforcement of a penalty of 0.5 per cent per month interest; and the regular use of delinquent notices.

Although foreclosure is provided as a means for enforcing collection of sewer rents, the Authority has not been obliged to initiate such action in view of the good collection record and the small amounts involved on the individual delinquent accounts. It has been found that persons or properties delinquent in payment of sewer rents are also delinquent in payment of general city taxes. In consequence, it is the practice of the City of Buffalo, in foreclosing the lien of its taxes, to have the amount and priority of the lien of the sewer rent determined, and the same is paid out of the proceeds of the sales. It is pertinent to report that under date of May 20, 1948, the Buffalo Sewer Authority, the City of Buffalo, and the County of Erie extended for an additional period of three years a participating agreement concerning proceeds from rental or sale of properties acquired at tax foreclosure sales or voluntary conveyance in lieu of tax foreclosure. It may also be of interest to report that from 1938 to June, 1950, uncollected sewer rents on assessed valuation are but slightly in excess of 0.5 per cent.

Allowances for Water Not Returned to Sewers

Allowances for water used in lawn sprinkling, rock gardens, automatic sprinkling systems, and other similar uses are handled on metered accounts by comparing with an average winter period. Flat rate accounts are all precomputed, by eliminating on permanent addressograph plates all such charges in rendering sewer rent bills for the summer season. May billings are $241,500, compared with November billings of $221,000.

Total and partial exemptions for general use of water not returned to sewerage facilities are now quite stabilized, numbering approximately 322 accounts that have been the subject of individual investigation and report. This has resulted in an approximate total rental waived of $150,000, as against $50,000 rental obtained.

Industrial Wastes

Payment of special charges for treatment of industrial wastes of unduly high concentrations, which cause increased treatment expense, is now an established practice. These special charges, which are for the purpose of reimbursing the Authority only for the cost of chlorine, chemicals, and power used for the disposal of waste in excess of normal sewage requirements, are determined from an adopted rate formula. Special charges (1) are regularly being made to a number of concerns whose wastes are particularly strong. The type of industry in which these concerns are engaged are rubber reclaiming, tanning, slaughtering, industrial laundering, etc. Cost of cleaning certain sewers is being directly assessed against two concerns whose wastes continue to cause blockage in these sewers. In all cases, payment of industrial waste charges has been made promptly.

Enforcement of Charges

When delinquent, the sewer charges constitute real property lien having the same priority and superiority as the lien of the general tax of the City of Buffalo. The sewer charge, if delinquent more than 90 days, may be im-

mediately foreclosed by the Authority in the Supreme Court, Erie County, N. Y. This is a much more effective method than the procedure for collection of general city taxes, which requires a sale of the tax certificate, and a two-year period of redemption before foreclosure.

Amendment of Schedule

Amendment of the "Schedule of Sewer Rents" requires publication once weekly for three successive weeks with notice that the proposed schedule will remain open for inspection in the office of the Authority for 30 days from the first date of the notice and that objections thereto may be filed during said period; the Authority may hear and examine any such complaints and may modify the proposed schedule and adopt a final schedule within 60 days after date of said notice. This procedure has been followed four times in amending the rate on assessed valuations, once in amending the rate on water use. Incidentally, one of the amendments was to reduce sewer rent based on assessed valuations (in 1942, reducing the amount required from $675,000 to $649,011, resulting in a reduction of 3.5¢ in the rate per $1,000 of assessed valuation).

For any not too substantial rate change, either way, it is preferable to consider sewer rent assessment as the more flexible source and the one that lends itself more readily to adjustment. Changing sewer rents based on water use is expensive, costing in excess of $6,000, and entails a great deal of laborious work in recalculating 80,000 original record cards and changing, accordingly, permanent addressograph plates for each individual account.

Out of Town Connections

Four communities have agreements with the Authority covering connections existing when the jurisdiction of the sewerage system was transferred to the Authority. These agreements provide for a permissive review of costs at 5-year intervals. The charge is based on total capacity of the respective connections as apportioned to total capacity of the sewage treatment plant of the Authority.

Due to over-all cost increases, it became necessary for the Authority to initiate such review in 1949, resulting in an increase from $1,022.73 to $1,397.91 per c.f.s., bringing approximately $12,000 more revenue to the Authority. This source produces an annual revenue of approximately $39,300.00.

TABLE I.—Revenue Comparison for Buffalo Sewer Authority

Source	Anticipated[1]	Actual[2]
Sewer rents:		
Assessed valuation		
Within city	$831,290.00	$845,000.00
Prior years	15,000.00	15,000.00
Housing	8,000.00	8,000.00
Outside city	3,000.00	4,000.00
	$857,290.00	$872,000.00
Water use		
Within city[3]	$900,000.00	$913,500.00
Bd. of Education	4,770.90	4,770.90
Outside city	10,000.00	8,000.00
	$914,770.90	$926,270.90
Other sources		
Industrial waste	$ 12,000.00	$ 12,000.00
Outside agreements	39,300.00	39,300.00
Agreement installments	4,543.00	4,543.00
	$ 55,843.00	$ 55,843.00
Interest income	$ 35,989.00	$ 40,989.00
Other income	$ 304.10	$ 5,304.10
	$1,864,197.00	$1,900,407.00

[1] For 1949–50 fiscal year.
[2] Estimate based on records of June 1, 1950.
[3] Includes both metered and flat rate services.

Anticipated and Actual Revenue

For convenience in summarizing the various revenue factors mentioned herein, Table I has been prepared to show the several revenue sources, the anticipated income from each, and the amounts it is estimated will be actually collected.

Reference

1. Symons, G. E., and Crane, F. W., "Special Sewer Service Charges for Industrial Wastes." *Water Works and Sewerage*, **91**, 3, 113 (Mar., 1944).

II. BATH, NEW YORK

By Frank Nollett

Superintendent, Electric, Gas and Water Systems, Bath, N. Y.

Bath, the county seat of Steuben County, is located in the rolling highlands of New York State's "Southern Tier." It is a relatively old community, having been settled in 1795; present population is about 5,000. Although no large industrial plants are located in the village, numerous small industries utilize most of the local labor supply. The village also caters to a large section of the farming area of the county, which in recent years has become an outstanding potato growing center. It is generally rated as a highly prosperous community.

The U. S. Veterans Administration Center, located on the outskirts of the village, maintains a 450-bed hospital and barracks with a capacity of 1,500 domiciliary patients. Of the 550 people employed at the institution, many live in the village. The Center has its own water and sewage plants although it maintains an emergency connection with the village water system.

Village Utilities

Since 1915, the village has owned and operated a diesel-driven electric plant of 2,000-kw. capacity. In 1920, the manufactured gas plant was purchased by the village, but was shut down in 1932 with the introduction of natural gas, which is piped to the gas plant and distributed through the old system. Because of the successful electric and gas operations, the water plant was purchased from the private owners in 1935. It has been an asset to the village from the time it was purchased. The plant supplies some 400,000 g.p.d. of ground water. All three of these utilities—gas, electricity, and water—are operated by a 5-man Municipal Commission.

The municipal sewer system and sewage treatment works were constructed in 1936. Sewers are on the separate plan. The treatment plant was designed for a population of 5,000 and includes a hand-raked bar screen, a manually-cleaned grit chamber, two rectangular mechanically-cleaned settling tanks, two fixed-cover digesters with heating coils but no stirring mechanisms, and glass-covered sludge drying beds. Chlorination equipment is operated throughout the year. The plant effluent is discharged into the Conhocton River, a portion of the Susquehanna watershed.

Sewage Works Financing

Construction was financed by a municipal bond issue of $81,000 and a Federal Public Works Administration grant of $66,000, making a total investment of about $147,000. Bond retirement is at a rate of $3,000 per year, the retirement and interest payments being met by a tax item in the village budget.

Shortly before the sewage treatment works were completed, the question of how to pay the operating expenses was given attention by the Municipal Commission, which was to be also charged with the operation of the sewerage system. The electric, gas, and water rate design had proven correct over a long period of years. These rates provided for a minimum charge plus a graduated consumption charge so that, as the consumption increased, the unit charges were less. It was decided to establish a sewer service rate with the metered use of water as the basis for the charge, the basic thought being that the sewer system and treatment works were a utility, just as were the gas, power, and water systems, and as

such, should be supported by a utility rate schedule that would make the system self-supporting. There was uncertainty, however, right at the start because it was not known how many users would connect to the system, what the cost of sewer maintenance and plant operation would be, and how much the customer would pay for the service on a rate basis without complaint.

TABLE I.—Quarterly Sewer Service Charges at Bath, N. Y.

Quantity[1]	Charge (Per 1,000 Gal.)	
	Gross	Net
First 15,000 gal. or less	$1.35[2]	$1.30[2]
Next 10,000 gal. or less	0.09	0.08
Next 25,000 gal. or less	0.07	0.06
Next 150,000 gal. or less	0.045	0.04
Next 300,000 gal. or less	0.021	0.02
Over 500,000 gal.	0.019	0.018
Minimum charge	1.35[2]	1.30[2]

[1] Based on water meter readings.
[2] Total charge.

At that time there was practically no information available regarding the use of similar plans of financing plant operation costs by New York State communities, although the fact was overlooked that such information would have been readily available from Ohio and many other states, which were even then making widespread use of sewer service charges. Nevertheless, the quarterly rate given in Table I was adopted April 2, 1937, and has been in effect since that date.

Method of Billing

It will be noted that the rate is based on a gross and net charge. The net bill is accepted on or before 10 days after date of bill. Bills are rendered quarterly as a part of the water bill, as the sewer rate is calculated from the water consumption. If several tenants are served through one water meter and the water charge is paid for by the owner, the sewer charge is figured from this meter and the owner billed. Where several tenants in one building have individual water meters, each tenant is billed for water and sewer use.

One laundry has its own water supply for washing purposes. In this case, the owner was induced to install a water meter on the well at his own expense. This plant uses the village water supply for drinking and other purposes. The two water meter consumptions are totaled to get the sewer charge. Since starting the sewer rental charge in 1937, no trouble has been experienced with the acceptance of this charge by customers. Another angle that appeals to the taxpayers in general is the fact that users of the system pay towards the operating expenses, thus relieving non-users of the system from a supporting tax charge for maintenance and operation.

A $30.00 connection fee is charged to cover the cost of tapping the main sewer and bringing the service line to the curb, where it is continued by the owner at his expense to a point inside the cellar wall. The connection charges are placed in the rental funds. When the system was new and many customers were connecting, this additional revenue made it possible to meet system operating expenses. However, for some time past, the cost of labor and materials have risen to a point where rentals have furnished only about half the funds needed to meet operating expenses—for example, in 1949, revenues were only $2,560.95, although expenses amounted to $4,821.25. The deficit presently is being made up from the Gas Department income, with the expectation that higher rentals will soon be adopted and the sewer system will get back on a paying basis the same as the other utilities.

The desire to revise the rate schedule for sewer service has been considerably strengthened by a recent review of current practice in Ohio, where it is

found that almost 150 communities—including Cleveland, Cincinnati, Columbus, Toledo, and even numerous villages having populations of less than 1,000—utilize such a plan of sewer service charges.

Bath's experience with the sewer rental plan has been uniformly good. Because this method is a fair and proper way to finance operating charges for a sewer system and treatment works, all communities are urged to give serious consideration to the plan.

NATIONAL PUBLIC HEALTH ENGINEERING CONFERENCE

"Suburban Sanitary Services" will constitute the theme of the Third National Public Health Engineering Conference to be held at Gainesville, Fla., October 23–24, 1950, under the sponsorship of the Department of Civil Engineering, University of Florida.

Special problems to be discussed in relation to suburban areas include:

1. Those created by boundary limitations.
2. Those attendant on medical requirements.
3. Those of the real estate developer.
4. Those of city officials.
5. Those of county officials.
6. Those of taxation.

Among the solutions of the problem to be discussed in detail are the following:

1. The sanitary district plan.
2. City and suburban planning.
3. Substitute measures.
4. Development of adequate water resources for fringe areas.
5. Experiences in other states.

CONSIDERATIONS IN THE SELECTION OF ENGINES FOR OPERATION ON SEWAGE SLUDGE GAS*

By Harold P. Hayes

Assistant Professor of Mechanical Engineering, University of Santa Clara, Santa Clara, Calif.

The problem of selecting engines for operation on sewage gas is necessarily a broad and difficult one. As it is virtually impossible to cover all phases of this problem in a paper of any reasonable length, the following discussion will be limited to a consideration of three questions:

1. Should engines operating on sewage sludge gas be designed as spark ignition or dual-fuel engines?
2. Should they be 2-cycle or 4-cycle engines?
3. Should they be supercharged or non-supercharged?

Basic Features

However, before beginning a discussion of these questions, it would be advisable to review briefly some of the basic features of engines designed for operation on sewage gas. These features concern primarily the air, the fuel, and the means of ignition. The air may be inducted into the cylinder by means of a simple suction stroke, or it may be forced into the cylinder by means of a blower or supercharger. The gas may be drawn into the engine directly with the air, or it may be injected into the cylinder under pressure, before or after the compression stroke. The mixture of air and gas may be ignited by means of a spark, or it may be ignited by means of a small amount of diesel fuel injected into the cylinder at the end of the compression stroke. The diesel fuel is itself ignited by the heat developed during the compression stroke of the engine. An engine which can operate on gas supplemented by a small amount of pilot oil, and which can also operate on 100 per cent diesel oil, is called a gas-diesel or dual-fuel engine. Strictly speaking, the engine can be called a dual-fuel engine only if the operation can be readily switched from gas to oil and back again, although the terms "gas-diesel" and "dual-fuel" are frequently used synonymously. If the intake, compression, power, and exhaust processes take place in 4 full piston strokes (2 crankshaft revolutions), the engine is a 4-cycle one. If these processes are made to take place in only 2 full piston strokes (1 crankshaft revolution), the engine is of the 2-cycle type. Thus, engines operating on sewage gas can be spark ignition or dual-fuel, supercharged or non-supercharged, and 2-cycle or 4-cycle engines.

Dual-Fuel Advantages

With these thoughts in mind, the three questions proposed earlier can now be considered. First of all, "Are spark ignition or dual-fuel engines more desirable for installation in a sewage treatment plant when the fuel used is sewage sludge gas?" The answer to this question lies primarily in the amount of sewage sludge gas available. If there is a surplus of gas, there is little to be gained by a dual-fuel engine installation. Low compression spark ignition engines can be purchased which are cheaper per installed horsepower than dual-fuel engines.

* Presented at 1950 Annual Meeting, California Sewage Works Assn.; Long Beach, Calif.; May 3–6, 1950.

Moreover, the pilot oil required for dual-fuel operation is an additional, unnecessary expense. However, if there is a shortage of gas, or if surplus power can be profitably disposed of, a dual-fuel engine has the following advantages:

1. Almost instantaneous changeover to stand-by fuel.—By definition, a dual-fuel engine is one which can be readily switched from one fuel to another. In most instances, this switch is almost instantaneous. In the case of the spark ignition gas engine, however, the problem of changeover is complicated by the difference in heating value between the sewage gas and the stand-by fuel. Normally, the incoming gas is metered by means of an orifice. As it is desirable to accomplish the changeover without changing this orifice in the intake gas line, it is necessary to dilute the stand-by fuel so that the heating value of the mixture is the same as that of the gas it replaces. When natural gas is used as the stand-by fuel, the problem is a relatively simple one. However, when propane or butane is the stand-by fuel, the problem becomes more difficult because of the large difference in heating value between these fuels and sewage sludge gas.

2. More economical operation during periods of plant operation on stand-by fuel.—Assuming that natural gas or electrical stand-by is not economically available, either propane or butane would be used as the stand-by fuel for a spark ignition engine. Either of these is more expensive, per B.t.u. of heat liberated, than diesel fuel. Granting the point that high compression spark ignition engines have been developed with efficiencies comparable to those of the dual-fuel engines, Table I illustrates the appreciable savings possible by the use of dual-fuel engines. For the given conditions, which are representative of the San Jose, Calif., area, the dual-fuel engine provides a saving of $155.00 per 100 hp.-month. During extended periods of operation on stand-by fuel—such as initial plant operation—this represents a substantial saving.

TABLE I.—Cost Comparison of Gas and Dual-Fuel Engines

Factor	Engine Type	
	Gas	Dual-Fuel
Load	Rated	Rated
Fuel	Propane	Diesel oil
Heating value (B.t.u./gal.)	85,000	132,000
B.t.u. rate (B.t.u./hp.-hr.)	7000	7000
Fuel cost ($/gal.)	0.095	0.107
Cost ($/100 hp.-month)	565	410

It should be noted that until recently the B.t.u. rate of spark ignition gas engines was about 9,000 B.t.u. per b. hp.-hr. at rated load. However, new developments by several engine manufacturers have produced spark ignition engines comparable to the dual-fuel engine in thermal efficiency. For this reason, the B.t.u. rates of the spark ignition and dual-fuel engines were assumed equal in Table I.

3. Ease of handling stand-by fuel.—There is no doubt that diesel fuel is more readily handled and stored than either propane or butane. From a safety standpoint alone, it is highly desirable that the use of propane and butane be avoided, if possible.

Dual-Fuel Disadvantages

Although the advantages mentioned cause the dual-fuel engine to appear in a favorable light, it has two principal disadvantages, as follows:

1. Initial cost.—As mentioned previously, a low compression spark ignition gas engine is cheaper per horsepower than a dual-fuel engine of corresponding rated horsepower and speed. There are two factors tending to offset each other in this respect:

(a) A low compression engine operating on the Otto (or explosion) cycle

TABLE II.—Catalogue Data on Comparable Gas and Dual-Fuel Engines

Engine Model	Bearing Area		Bore and Stroke (in.)	No. of Cyl.	Output at 360 R.P.M. (hp.)	Initial Cost ($)	
	Main (sq. in.)	Crankpin (sq. in.)				Total	Per Hp.
SI gas	64.8	65.8	15½×17½	6	600	40,600	67.67
Diesel	64.8	65.8	13¼×17½	7	615	48,125	78.25

has lighter bearing loads than a corresponding dual-fuel engine.

(b) A dual-fuel engine can be rated at a higher output per cubic inch of displacement than a corresponding low compression gas engine.

Catalogue data from a well-known manufacturer (Table II) illustrates the effect of these two factors on initial cost. Basically, the engines are of the same design, as evidenced by identical bearing areas and strokes. However, because the operating pressures in the SI engines are less than those in the diesel (or dual-fuel) engines, a larger bore can be used in the gas engine without causing any increase in bearing load. Thus, even though the mean effective pressure of the diesel or dual-fuel engine is higher, it takes 7 cylinders to produce the horsepower obtained from a larger bore, 6-cylinder gas engine. As it costs more to add a cylinder than to increase the bore of the cylinders, the diesel engine or dual-fuel engine is more expensive per horsepower than the gas engine.

It should be noted that the newly developed high compression spark ignition engine lies between the dual-fuel engine and the low compression spark ignition engine in initial cost. Figures provided by one manufacturer show the dual-fuel engine to be about 2 per cent more costly than the high compression spark ignition engine.

2. Cost of pilot fuel.—One of the principal objections to dual-fuel engines is the cost of the necessary pilot oil. The percentage of pilot oil required at loads varying from light load to full load is open to considerable dispute. However, the general consensus is that between 5 and 10 per cent is required at rated loads, and about 15 per cent at light loads. Some manufacturers maintain that a low grade of diesel fuel can be used as pilot oil, but the desirability of this is open to question. Based on cost figures in the San Jose area for high-grade diesel fuel (10.7¢ per gal.), 10 per cent pilot oil, operation at rated load, and 7,000 B.t.u. per b.hp.-hr., the cost of pilot oil would be about $500 per 100 hp.-year. Certainly, if there were a guarantee of sufficient sewage gas at all times, the cost of pilot fuel would be a needless expense. However, if there is a large deficiency of gas, the economy of diesel make-up fuel in comparison to propane or butane for a gas engine will probably justify the use of dual-fuel engines. There will obviously be many borderline cases, for which the deciding factors will probably be those other than cost.

In summary, then, if there is a large surplus of gas, a low compression spark ignition engine is advisable. If there is a large deficiency of gas (more than about 10 per cent), a dual-fuel engine is advisable because diesel fuel is a cheaper and more readily handled stand-by fuel than either propane or butane. For borderline cases between these two, the newly developed high compression spark ignition engines must be considered in addition to the factors of safety, maintenance, ease of converting to the stand-by fuels, etc.

2-Cycle *vs.* 4-Cycle Engines

The principal differences between 2-cycle and 4-cycle engines may be briefly summarized as follows:

1. Factors affecting size and weight.—Because the 2-cycle engine develops a power stroke for every revolution of the crankshaft, it should be capable, ideally, of producing twice the output of a 4-cycle engine with the same piston displacement. Thus, the 2-cycle engine offers a potential saving in size and weight. However, 2-cycle engines are not rated at as high a mean effective pressure as 4-cycle engines. There are two schools of thought on the reason for this. One is the danger of overheating the piston and the other engine parts because fuel is burned during every crankshaft revolution, instead of during every other crankshaft revolution as in the 4-cycle engine. The other thought is that 2-cycle engine manufacturers are simply conservative in their engine ratings. In any event, a typical 2-cycle engine would be rated at 70 p.s.i., m.e.p. (mean effective pressure), whereas the corresponding 4-cycle engine would be rated at 85 or 90 p.s.i., m.e.p. In addition to this lower rating, the 2-cycle engine requires a blower and a complicated blower drive mechanism. In actual practice, these factors combine in such a way that a 2-cycle engine is almost as heavy as a 4-cycle engine of the same power output.

2. Gas admission.—In the unsupercharged, 4-cycle dual-fuel engine, the gas is directed to a point directly behind the air intake valve and is then admitted to the combustion chamber with the intake air. In the 2-cycle engine, air is admitted to the cylinder until the ports close, and the gas is then injected into the cylinder under a relatively low pressure. A design of the latter type presents three problems—timing of the gas admission to insure that none of the gas charge is lost during the scavenging process, providing sufficient turbulence to insure thorough mixing of the gas and air, and properly directing the intake air to insure thorough scavenging of the exhaust products.

Engine manufacturers are in wide disagreement on these problems. Some insist that in 2-cycle engines of 500 hp. and less, scavenging is poor and charge stratification exists. These factors lead to detonation and roughness, particularly at light loads. Others insist that scavenging and mixing are as good, if not better, in the 2-cycle than in the 4-cycle engines. It is interesting to note that, although gas admission and scavenging are very similar in the 2-cycle and supercharged 4-cycle engines, there are no indications that supercharged 4-cycle engines are unsatisfactory in operation.

This is one of the age-old arguments, which will undoubtedly continue for many years. The principal issues at stake are particularly hard to evaluate. However, dual-fuel engines of both 2-cycle and 4-cycle are operating successfully in various parts of the country. Moreover, 2-cycle engines had such an outstanding war record that it is difficult to dispute their reliability. Further, although 4-cycle engines are generally favored in the United States, except in very large sizes, 2-cycle engines have generally been favored in Europe. A question of such almost international scope can hardly be settled by a single paper. The best conclusion is that as both types are now successfully operating, the choice between the two should depend primarily on cost quotations and specific engine details. Particular attention should be paid to the piston speeds called for in the engine specifications. Too low a specified piston speed gives the 2-cycle engines an advantage, whereas too high a specified piston speed gives 4-cycle engines the advantage.

Supercharging

A supercharger, as mentioned earlier, is merely a blower that forces air into the engine cylinders under positive pressure. It is a means of increasing engine output, because when more

air is admitted to the cylinders, more fuel can be burned, hence more power developed. Strictly speaking, a 2-cycle engine with blower is actually supercharged, although the blower pressures are kept low in comparison to those used in supercharged 4-cycle engines. However, the following remarks are confined to 4-cycle engines of either the spark ignition or dual-fuel type.

There are three principal advantages claimed for a supercharged engine:

1. Lower cost per horsepower in large engine sizes.—Supercharging is essentially a substitute for actually increasing the piston displacement of an engine. In small sizes, the cost of increasing piston displacement is relatively low and the supercharger is thus comparatively expensive. However, as the engine size increases, the cost of increasing piston displacement becomes very large and the supercharger is thus relatively inexpensive. Hence, there is some engine size at which supercharging becomes desirable from a cost standpoint.

Although there is some disagreement on this point, the dividing line seems to be at about 500 hp. In sizes of about 500 hp. and up, a supercharged engine generally costs less per horsepower than an unsupercharged engine of the same speed. Roughly speaking, the cost per horsepower for a supercharged dual-fuel engine may be as much as $10 less than that for a nonsupercharged dual-fuel engine.

2. Better operating economy.—Supercharging an engine tends to give it a flatter economy curve; that is, more economical operation at part load. It also is claimed that the B.t.u. consumption rate (at full load) of a supercharged engine is slightly less than that of an unsupercharged engine. Although these differences are small, they are still points in favor of supercharging.

3. Longer engine life.—When considering the wear on valves, rings, and bearings in supercharged engines, the question naturally arises as to whether the increased pressures and temperatures resulting from supercharging bring about increased engine wear and appreciably shortens engine life.

From the pressure standpoint, the answer is yes, unless certain design changes are made to compensate for the increased pressure. However, most manufacturers, recognizing the trend toward supercharged engines, have made the necessary changes in crankshaft size and bearing areas. The result of these changes is that most dual-fuel engines offered alternatively as supercharged and unsupercharged engines have been designed to withstand the supercharged conditions, and are actually overdesigned when operated as unsupercharged engines. Thus, the answer to the pressure problem is one of viewpoint more than anything else.

From the temperature standpoint, it must be remembered that the scavenging air from the supercharger does an excellent job of cooling the hot exhaust gases. Consequently, the exhaust valve life will actually be prolonged when an engine is supercharged, as the exhaust gases are cooler than in the unsupercharged engine. Moreover, although the average temperature of the engine cycle is raised by supercharging, the temperature itself has little to do with engine wear. It is temperature unbalance which causes cylinder liner wear and there is no reason why there should be any more temperature unbalance in a supercharged than in an unsupercharged engine. The scavenging air actually helps the cooling water to remove heat from the cylinder. Thus, less heat is available there to be conducted along the cylinder walls. As long as the cylinder walls do not have any appreciable distortion, there should be very little cylinder liner or ring wear. This is much the same point made in vapor phase cooling of engines. A high cylinder wall temperature is not unde-

sirable unless there is a temperature unbalance, or unless the temperature is so high that structural damage or lubrication trouble is produced.

Supercharging has the additional advantage of purging any unburned fuel from the cylinder. Glowing particles of unburned carbon, for example, lead to untimed explosions in the cylinder. The excess air introduced by supercharging would thus be particularly valuable in case the pilot fuel were a cheap grade of oil, difficult to burn completely.

Summary

The trend to supercharged engines is becoming more pronounced with each passing year. It is an economical means of increasing engine output, and it produces no harmful effects with respect to engine life.

This paper has covered rather briefly questions of spark ignition *vs.* dual-fuel engines, 2-cycle *vs.* 4-cycle engines, and supercharged *vs.* non-supercharged engines. There are undoubtedly many more interesting points that could be discussed in the selection of engines for operation on sewage sludge gas. It is to be hoped that the many manufacturers' representatives and operating engineers will be as kind and cooperative toward everyone faced with these problems as they were to the author in the preparation of this paper.

Acknowledgment

Grateful acknowledgment is made to the many manufacturers' representatives and operating engineers who so kindly cooperated in the furnishing of data and operation records on which the conclusions of this paper are based.

MAKE YOUR HOTEL RESERVATIONS FOR THE WASHINGTON MEETING

The Hotel Statler at Washington, D. C., will be the headquarters for the Twenty-Third Annual Meeting of the Federation in October.

Requests for room reservations should be addressed directly to the hotel. Note that the technical program will open on Monday morning, October 9, and will close at noon on Thursday, October 12.

WRITE NOW FOR YOUR RESERVATIONS!

ACTIVATED SLUDGE STUDIES

I. EFFECT OF SLUDGE AGE ON OXIDIZING CAPACITY

By C. E. Keefer and Joseph Meisel

Deputy Sewerage Engineer and Senior Chemist, respectively, Bureau of Sewers, Baltimore, Md.

From the beginning of the activated sludge process it was recognized that the oxidation of sewage by this process depended to a considerable extent on the characteristics of the sludge. The investigations described in these studies indicate how certain of these characteristics affect the purification of sewage.

General Procedure

The purpose of the experiments was to determine how the electrode potential (E_h) of both unaerated and aerated activated sludge varied with its age, and what effect the mixing of this sludge with primary settling tank effluent without subsequent aeration would have on the 5-day B.O.D. of the effluent. The sludge was obtained immediately after its withdrawal from the settling tanks following the activated sludge aeration tanks at the Back River sewage treatment plant serving Baltimore, Md.

The E_h of the sludge was measured at predetermined time intervals by means of a Beckman potentiometer, using three platinum electrodes each 15 cm. long. The sludge was preaerated during some of the tests and unaerated during others. A sufficient volume of each of the sludges then was added to settled sewage so that there was approximately 1,000 p.p.m., of suspended solids in the mixture. After gently stirring the sludge and the sewage for 3 min., the dissolved oxygen and the E_h of the mixture were determined. During this mixing period no air was added. The mixture was then allowed to settle for 2 hr., and the 5-day B.O.D. of the supernatant was determined.

Experiment No. 1

Two samples of sludge were obtained. The E_h values (Table I) of these sludges were + 59 and + 158 millivolts at the beginning of the observations. At no time was air added to either of the sludges. At the end

TABLE I.—Effect of Unaerated Activated Sludge on the B.O.D. of Settled Sewage

Sludge		Mixture[2]		5-day B. O. D.		
Age (hr.)	E_h[1] (mv.)	D.O.[3] (p.p.m.)	E_h[3] (mv.)	Primary Effluent (p.p.m.)	Treated Effluent[4] (p.p.m.)	Removal (%)
			(a) Test No. 1			
0	+ 59	1.2	+ 58	172	136.0	20.9
1	− 55	1.2	+ 22	172	156.0	9.3
2	− 70	1.2	+ 20	172	156	9.3
3	− 70	1.2	+ 20	172	164	4.7
4	− 75	1.2	+ 20	172	164	4.7
5	− 75	1.2	+ 20	192	188	2.1
6	−120	1.2	− 1.5	192	188	2.1
			(b) Test No. 2			
0	+158	3.0	+214	84	86	− 2.4
1	− 21	3.0	+120	84	94	−11.9
2	− 31	3.0	+ 99	84	100	−19.1
3	− 52	3.0	+ 88	84	100	−19.1
4	− 87	3.0	+ 20	100	124	−24.0
5	− 86	3.0	+ 50	100	120	−20.0
6	− 86	3.0	+ 35	100	120	−20.0

[1] Unaerated.

[2] Unaerated mixture of sludge and primary tank effluent.

[3] Determined after mixing for 3 min.

[4] Liquor decanted after 2-hr. settling of mixture.

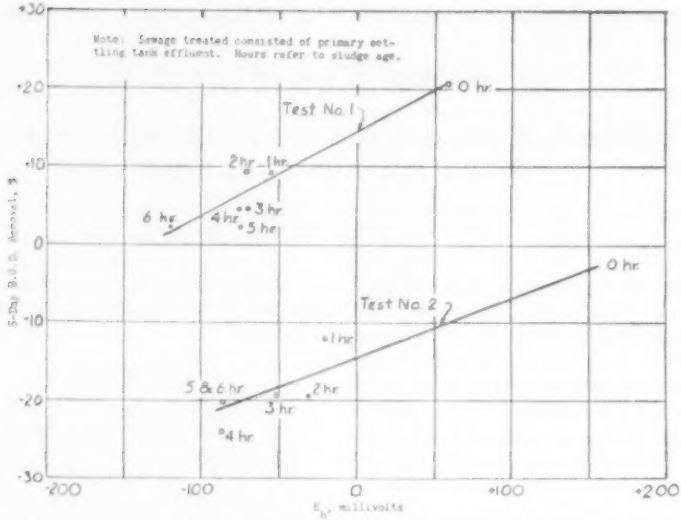

FIGURE 1.—Relationship between E_h of unaerated activated sludge and reduction in B.O.D. of added sewage. (Mixture not aerated.)

of each hour for a 6-hr. period the E_h of the sludge was determined and a portion of the sludge was added to primary settling tank effluent. After mixing the two for 3 min., the sludge was allowed to settle for 2 hr. The 5-day B.O.D.'s of the decanted liquors are given in Table I; the relationship between the E_h of the activated sludge and the removal of the B.O.D. from the sewage is shown in Figure 1.

The E_h of the sludge decreased during a 6-hr. period from + 59 to − 120 millivolts in Test 1, and from + 158 to − 86 millivolts in Test 2. Although the E_h of the primary settling tank effluent was not determined, it was such that in every instance but one it raised the E_h of the activated sludge. The sludge (Test 1) that was 0 hr. old reduced the 5-day B.O.D. of the sewage 20.9 per cent. At no time while the sludge and the sewage were in contact was air added. Holding the sludge for 6 hr. and then bringing it in contact with the sewage for 3 min. resulted in a 2.1 per cent reduction in the 5-day B.O.D. of the sewage.

During Test 2, which was conducted in the same manner as Test 1, mixing the sludge and the sewage for 3 min. and then settling the mixture for 2 hr. produced a decanted liquor with a higher B.O.D. than that of the sewage. These negative results were obtained in spite of the fact that the D.O. and the E_h of the mixtures were greater than the results obtained during Test 1, where positive removals were observed.

Experiment No. 2

During the second experiment, the sludge was unaerated for the first 3 hr. and then aerated for the next 45 hr. As in the tests of Experiment No. 1, the sludge was added to settled sewage and the effect of the sludge on the B.O.D. of the sewage was observed. (Table II and Figure 2). The E_h of the unaerated sludge decreased from + 87 to − 73 millivolts in 3 hr. Although the E_h of the mixture of sewage and sludge was positive, the 5-day B.O.D. of the supernatant after 2 hr. of settling was greater than the sewage being treated. After holding the

TABLE II.—Effect of Unaerated and Aerated Activated Sludge on the B.O.D. of Settled Sewage

Sludge		Mixture[1]		5-day B. O. D.		
Age (hr.)	E_h (mv.)	D.O.[2] (p.p.m.)	E_h[2] (mv.)	Primary Effluent (p.p.m.)	Treated Effluent[3] (p.p.m.)	Removal (%)
			(a) Sludge Unaerated			
0	+ 87	3.0	+ 97	128	144	−12.5
1	− 4	3.0	+ 48	128	156	−21.9
2	− 36	3.0	+ 44	128	156	−21.9
3	− 73	2.6	+ 23	128	156	−21.9
			(b) Sludge Aerated			
4	+ 3	2.6	+ 88	128	113	+11.7
5	+ 27	3.2	+ 90	148	128	+13.5
6	+ 50	3.2	+101	148	124	+16.2
24	+331	4.5	+221	100	80	+20.0
48	+320	4.4	+170	124	80	+35.4

[1] Unaerated mixture of sludge and primary tank effluent.

[2] Determined after mixing for 3 min.

[3] Liquor decanted after 2-hr. settling of mixture.

sludge for 3 hr., it was then aerated. Preaeration for 1 hr. increased the E_h from − 73 to + 3 millivolts. This sludge produced a B.O.D. removal in the primary settling tank effluent of 11.7 per cent. Preaeration for 3 hr. increased this removal to 16.2 per cent; 21 hr., to 20.0 per cent; and 45 hr., to 35.4 per cent. Holding the sludge for 3 hr. before aerating it apparently had a detrimental effect on its subsequent oxidizing capacity, as preaeration for 45 hr. removed only 35.4 per cent of the 5-day B.O.D. of settled sewage.

Experiment No. 3

During Experiment No. 3 the sludge was aerated for 3 hr., followed by a period of 3 hr. when no air was added. The fresh sludge as drawn before aeration effected a removal of 6.3 per cent (Table III and Figure 3) in the 5-day B.O.D. of settled sewage. Aerating the sludge for 1 hr. and bringing it in contact for 3 min. with settled sewage without further aeration resulted in a 5-day B.O.D. removal of 53.1 per cent.

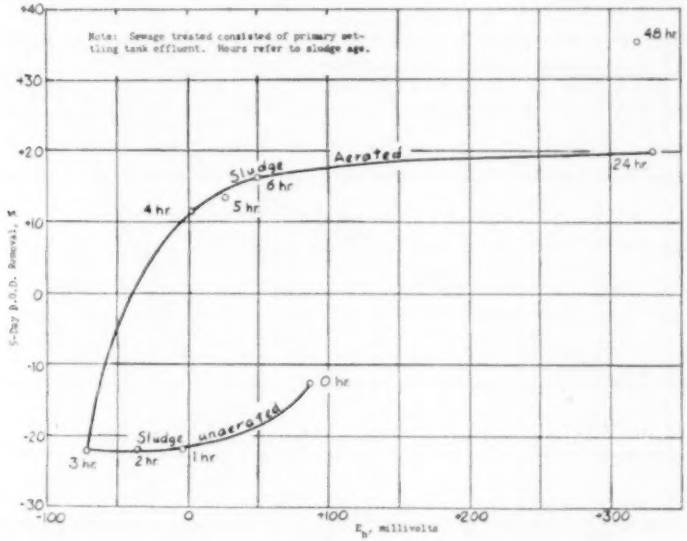

FIGURE 2.—Relationship between E_h of activated sludge stored and then aerated and reduction in B.O.D. of added sewage. (Mixture not aerated.)

TABLE III.—Effect of Aerated and Unaerated Activated Sludge on the B.O.D. of Settled Sewage

Sludge		Mixture[1]		5-day B. O. D.		
Age (hr.)	E_A (mv.)	D.O.[2] (p.p.m.)	E_A[2] (mv.)	Primary Effluent (p.p.m.)	Treated Effluent[3] (p.p.m.)	Removal (%)
(a) Sludge Aerated						
0	+170	4.4	+194	64	60	6.3
1	+270	5.2	+273	64	30	53.1
2	+294	5.6	+297	64	26	59.4
3	+311	6.0	+303	64	22	65.2
(b) Unaerated						
4	− 87	3.6	+ 83	68	52	23.5
5	−114	3.0	+ 83	68	54	20.6
6	−114	3.0	+ 83	68	58	14.7

[1] Unaerated mixture of sludge and primary tank effluent.
[2] Determined after mixing for 3 min.
[3] Liquor decanted after 2-hr. settling of mixture.

Aeration for 3 hr. increased this removal to 65.2 per cent. These tests indicate the effectiveness of preaerating activated sludge.

After aeration was discontinued, there was a rapid reduction (Figure 4) in the E_A of the sludge. During the first hour after aeration was discontinued the E_A dropped from + 311 to − 87 millivolts; at the end of 3 hr. the E_A was − 114 millivolts. Even after a non-aerating period of 3 hr., the sludge was capable of reducing the 5-day B.O.D. of settled sewage 14.7 per cent.

Experiment No. 4

The activated sludge was aerated for 6 hr. during Experiment No. 4. The E_A increased quite rapidly from + 133 to + 284 millivolts during the first hour of aeration (Table IV). At the end of 6 hr. the E_A was + 415 millivolts. It is interesting to note that the sludge before being aerated reduced the 5-day B.O.D. of settled sewage 39.3 per cent (Figure 5) when brought in contact with the sewage for 3 min. followed by 2 hr. of settling. Sludge that had been aerated for 6 hr. produced a 60 per cent removal of 5-day B.O.D. in settled sewage.

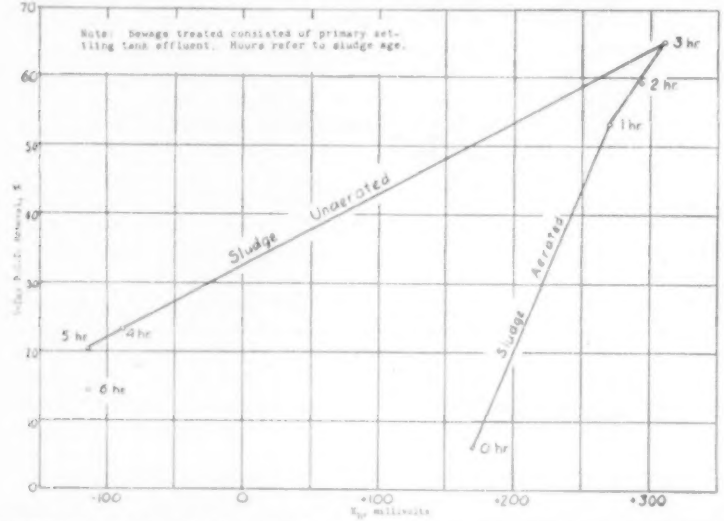

FIGURE 3.—Relationship between E_A of activated sludge aerated and then stored and reduction in B.O.D. of added sewage. (Mixture not aerated.)

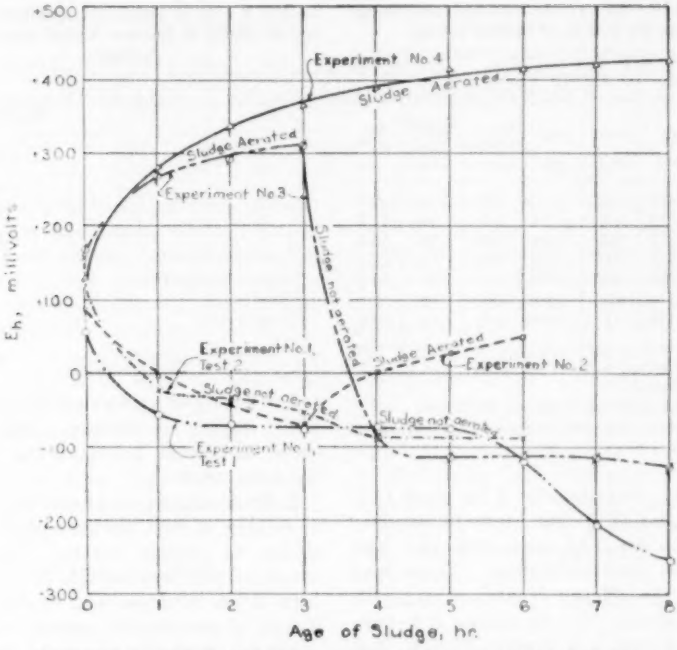

FIGURE 4.—Relationship between age and E_h of activated sludge.

Discussion

As had been indicated by previous investigators (1)(2)(3), determining the E_h of activated sludge gives information about the sludge that is of value. Although sludges with negative values may be capable of reducing the B.O.D. of sewage (Table I, Test 1, and Table III), it is more likely that such sludges will have a detrimental effect (Table I, Test 2, and Table II). In every instance where the sludge was aerated—even for as little as 1 hr.—it was capable of reducing the B.O.D. of

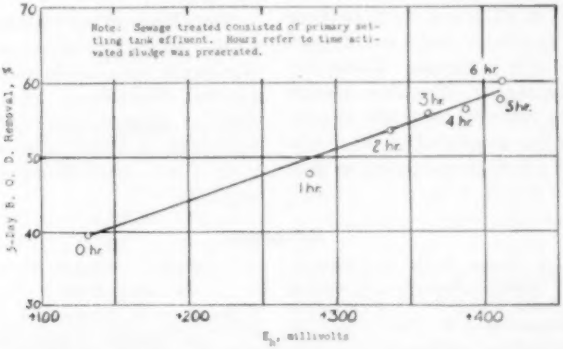

FIGURE 5.—Relationship between E_h of aerated activated sludge and reduction in B.O.D. of added sewage. (Mixture not aerated.)

TABLE IV.—Effect of Aerated Activated Sludge on the B.O.D. of Settled Sewage

Sludge		Mixture[1]		5-day B. O. D.		
Age (hr.)	E_h (mv.)	D.O.[2] (p.p.m.)	E_h[2] (mv.)	Primary Effluent (p.p.m.)	Treated Effluent[3] (p.p.m.)	Removal (%)
0	+133	2.0	+112	168	102	39.3
1	+284	3.2	+180	168	88	47.6
2	+339	3.2	+180	168	78	53.5
3	+365	4.0	+184	168	74	55.9
4	+390	3.8	+171	160	70	56.2
5	+414	4.0	+189	160	68	57.5
6	+415	4.0	+200	160	64	60.0

[1] Unaerated mixture of sludge and primary tank effluent.
[2] Determined after mixing for 3 min.
[3] Liquor decanted after 2-hr. settling of mixture.

sewage. Aeration for 1 hr. gave 11.7, 47.6, and 53.1 per cent reductions; aeration for 3 hr. gave 16.2, 55.9, and 65.2 per cent reductions. These tests reveal the efficacy of preaerating activated sludge prior to adding it to sewage. There is a possibility that less aeration tank volume and less air are required where the sludge is preaerated in a separate tank or in the inlet end of a step aeration tank, than where the sludge and the sewage are introduced into the inlet end of the conventional aeration tank.

No correlation was found to exist between the E_h of unaerated but freshly drawn activated sludge and its effectiveness in reducing the B.O.D. of sewage. The sludge with an E_h potential of +158 millivolts (Table V) increased the B.O.D. of settled sewage 2.4 per cent, whereas another sample of sludge with an E_h of +59 millivolts caused a B.O.D. reduction of 20.9 per cent.

TABLE V.—E_h of Unaerated Activated Sludge and Its Ability to Remove B.O.D. from Settled Sewage[1]

Experiment No.	Sludge E_h (mv.)	5-day B. O. D. Removal (%)
1[2]	+ 59	+20.9
1[3]	+158	− 2.4
2	+ 87	−12.5
3	+170	6.3
4	+133	39.3

[1] Age of sludge: 0 hr.
[2] Test No. 1.
[3] Test No. 2.

Conclusions

1. The E_h of activated sludge and mixed liquor in aeration tanks indicates the extent to which the sludge has been aerated.

2. Preaerating activated sludge prior to mixing it with sewage enhances its ability to oxidize sewage. The preaerated sludge was capable of removing from 6.3 to 65.2 per cent of the 5-day B.O.D. of sewage; the amount removed depended on the length of the preaeration period and the condition of the sludge before aeration was started.

3. Preaerating activated sludge in separate tanks before it is added to sewage or the inlet end of step aeration tanks may be more economical than mixing and aerating unaerated sludge and sewage in aeration tanks.

Acknowledgments

The Back River sewage treatment works, where the above-mentioned experiments were conducted, is under the general direction of Paul L. Holland, director, Department of Public Works, and John J. Hunt, sewerage engineer, with Prof. Abel Wolman, consulting engineer.

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THE SURVIVAL OF TUBERCLE BACILLI IN SEWAGE TREATMENT PROCESSES *

By David Pramer and H. Heukelekian

Various investigations have demonstrated the presence of tubercle bacilli in sanatoria wastes, throughout sewage treatment plants of sanatoria, and in the streams receiving such wastes and plant effluents. Because tubercle bacilli have a considerable capacity to survive outside of their animal host, and this ability to survive may favor spread of the disease, the public health menace involved and the need for a study of the fate of the t. b. organism in sewage treatment processes require no elaboration.

Method of Study

Before the survival of tubercle bacilli in sewage treatment processes could be studied a method whereby these organisms could be quantitatively isolated from highly contaminated substrates was required. A literature survey yielded no method that was quantitatively reliable. Therefore, the first step was to develop a procedure capable of suppressing contaminants without inhibiting the growth of any tubercle bacilli present.

There were three means by which the desired end could be accomplished:

1. By use of a selective medium.
2. By use of a selective pretreatment procedure.
3. By use of a combination of pretreatment and cultivation on a selective medium.

The avian tubercle bacillus was utilized as the test organism; each possibility was approached and systematically studied.

Dubos agar medium was chosen as a starting point and attempts were made to render it selective. The addition of dyes and of sulfadiazine in the concentration required to suppress the organisms normally present in sewage was found to inhibit tubercle bacilli as well and so was not applicable. A study of various anti-biotics showed them to be selective in their action. Experimentation showed that addition of 50 units of penicillin and 50 units of grisein per cc. of medium inhibited 74 to 82 per cent of the normal sewage organisms without suppressing growth of the test organism.

Use of acid and alkaline solutions for pretreatment of a sample was found not applicable when quantitative results were desired, and of the other pretreatment methods that were suggested, heat appeared the most practical. Study showed exposure to 50° C. for 30 minutes to have no effect on the number of tubercle bacilli present, but yielded a 60 per cent reduction in sewage organisms.

A combination of preheating for 30 minutes at 50° C. and plating on Dubos medium that has been solidified with agar and modified by the addition of 5 units of penicillin and 50 units of grisein per cc. will yield an 89 per cent to more than 97 per cent inhibition of the organisms normally found in sewage, without significantly suppressing growth of tubercle bacilli present.

Plates are poured, allowed to solidify and incubated overnight to eliminate some of the water of condensation and allow any contamination to grow out. The inoculum is placed upon the surface of the plate. The dilution blanks used are prepared by mixing one part

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

TABLE I.—Efficiency of Method for Quantitative Recovery of Tubercle Bacilli from Contaminated Material

Penicillin (units per cc.)	Number of Replications	Tubercle Bacilli Recovery (%)		Sewage Organisms Reduction (%)	
		Range	Mean	Range	Mean
3	5	88 to 110	98	83 to 93	87
4	4	88 to 104	96	88 to 93	88
5	4	87 to 101	96	89 to 97	93
7	3	63 to 81	72	92 to 98	95

basal medium with three parts distilled water. The dilution blanks are liquefied, cooled to 45° C., dilutions run; and following inoculation with 1 cc., the plate is immediately rotated. Time is allowed for the inoculum to solidify and the plates are incubated at 37° C. Counts, to determine the sewage organisms present, are made following 48-hr. incubation and all colonies developed within that time are marked. Plates inoculated with a pure culture of *Mycobacterium avium* show no growth following 48 hr. of incubation. All plates are rechecked following 7 days of incubation to obtain the number of tubercle bacilli present. The differential time of incubation required for growth of normal sewage organisms and tubercle bacilli is thereby utilized as an integral part of the method.

Table I shows the efficiency of the method obtained by pretreatment at 50° C. for 30 min., plating on Dubos medium modified with 50 units of grisein per cc. and varying concentrations of penicillin.

Sewage was inoculated with avian tubercle bacilli and subjected to various treatment processes in the laboratory. Survival of the organisms was determined by the developed procedure as given.

The sewage treatment plant of a New Jersey tuberculosis sanatorium was surveyed in an effort to demonstrate and study the survival of tubercle bacilli under natural conditions. In this study the method was modified to include one month of incubation.

Test Results

Table II summarizes the results obtained in laboratory studies of the survival of *Mycobacterium avium* in various sewage treatment processes. Quiescent sedimentation for 3 hr. showed no significant reduction in the number of tubercle bacilli present. Chemical coagulation with ferric chloride at pH 5.0, followed by flocculation and sedimentation, removed more than 99 per cent of the tubercle bacilli in the sewage.

Continuous application of sewage to sand filters yielded a much higher removal of the tubercle bacilli than when intermittent flooding was utilized. Efficient sand filtration removed more than 99 per cent of the t. b. organisms. Aeration for 24 hr. at as high a rate as 22 cu. ft. per gal. per day had little effect on the removal of tubercle bacilli.

The effectiveness of chlorination was determined by correlating the free chlorine residual with the number of tubercle bacilli surviving. A free chlorine residual of 0.9 p.p.m. was found necessary to obtain what might be considered sterilization. This is equivalent to 2 to 5 p.p.m. residual as determined by ortho-tolidine and is much higher than that normally maintained in the field.

TABLE II.—Removal of Tubercle Bacilli by Various Sewage Treatment Processes

Treatment Process	Tubercle Bacilli per Cc.		% Removed
	Before Treatment	After Treatment	
Sedimentation for 3 hr.	680,000	670,000	0
Chemical coagulation with ferric chloride	530,000	200	99+
Sand filtration:			
(a) flooding	59,000	10,200	83
(b) drip application	370,000	1,500	99+
Aeration	1,180,000	900,000	26
Chlorination to 0.9-p.p.m. free Cl. residual	118,000	<5	99+

Survey of a sanatorium sewage treatment plant (including primary sedimentation, trickling filters, sludge digestion, and chlorination) has yielded isolation of acid-fast bacilli morphologically identical with *Mycobacterium tuberculosis*. As yet, it has not been possible to run animal inoculation studies to determine the pathogenicity of these organisms, but results show the organisms to be present in a concentration of 1,500 per cc. in the raw sanatorium waste and 10 per cc. in the treatment plant effluent. The indicated number in fresh solids and ripe sludge is 100,000 per cc. and 10,000 per cc., respectively.

Summary and Conclusions

Utilizing a newly developed method capable of quantitatively isolating tubercle bacilli from contaminated material, a laboratory and field study to determine the survival of tuberculosis organisms in sewage treatment processes has been made. From the study the following conclusions may be drawn:

1. The removal of tubercle bacilli by sedimentation, chemical coagulation, and sand filtration is of the same order as the removal of the organisms normally present in sewage.

2. Chlorine residuals as maintained in the field are not sufficient to yield an effluent free of tubercle bacilli. A free chlorine residual of 0.9 p.p.m. was found necessary to reduce the number of tubercle bacilli from 118,000 per cc. to less than 5 per cc.

3. Acid-fast bacilli, morphologically identical to *Mycobacterium tuberculosis*, have been isolated from various phases of a sanatorium treatment plant. Their indicated concentration is 1,500 per cc. in the raw waste, 100,000 per cc. in fresh solids, 10,000 per cc. in ripe sludge, and 10 per cc. in the plant effluent.

4. If removal of tubercle bacilli is taken as the criterion, a combination of chemical coagulation, sand filtration, and chlorination to a 1.0-p.p.m. free chlorine residual would constitute efficient treatment and yield an effluent free of virulent tuberculosis organisms.

Acknowledgment

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SIGNIFICANCE OF GRAM-STAINED SMEARS IN THE DETERMINATION OF *ENTEROCOCCUS* M.P.N.

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A procedure for the enumeration of the *Enterococcus* by the "Most Probable Number" (M.P.N.) method was described by Winter and Sandholzer in 1946 (1). The procedure described by these authors is divided in two parts—a presumptive and a confirmatory test. In the presumptive procedure, a positive reaction consists of growth in the broth and the fermentation of the dextrose with the production of acid in 18 to 24 hr. of incubation at 45.5° C. Such a positive reaction presumes the presence of the *Enterococcus* group, whereas the absence of growth, according to the authors, proves the *Enterococcus* are not contained in the sample planted. Positive tubes require confirmation.

The positive presumptive tube supplies young, actively growing streptococci for the confirmatory procedure. Furthermore, the growth of many species of interfering organisms are inhibited in the dextrose azide broth incubated at 45.5° C.

The positive confirmatory test for the *Enterococcus* consists of the demonstration of growth of gram-positive, ovoid streptococci as "pin-point" colonies on dextrose azide agar containing 0.001 per cent methylene blue; growth in dextrose azide methylene-blue broth containing 6.5 per cent sodium chloride and 650 Oxford units of penicillin per liter; and a negative catalase test.

This procedure has been used extensively in sanitary investigations as a supplementary test to the coliform procedures described in "Standard Methods" (2). In such surveys, to obtain an adequate amount of factual information, it is necessary to process a large number of samples each day with a minimum of space, equipment, and personnel. Any simplification of the procedure, with no appreciable loss in the accuracy of the M.P.N., is desirable.

The study described herein represents the examination of 332 miscellaneous samples for the presence of *Enterococcus*. The specimens consisted of fresh sewage, sewage stored up to 6 weeks at temperatures from 5° to 37° C., and waters from springs, wells, rivers, and lakes.

Methods

In the presumptive tests, tubes were incubated 20 to 24 hr. in a water bath at 45.5° C. (± 0.5° C.) All tubes with turbidity and acidity (indicator changed from blue to yellow or greenish-yellow color) were considered positive presumptive tubes. One 3 mm. loop of broth from the positive tube was inoculated in the broth portion, and a second loopful streaked across the agar portion of the combined "slant-broth" confirmatory tube. All such confirmatory tubes were incubated 24 hr. at 37° C.

The individual *Enterococcus* examinations were made by several bacteriologists in performing their routine procedures. Subsequent data represents their composite findings. The "slant-broth" confirmatory tube was examined critically for the typical growth of the *Enterococcus*. The validity of this observation was tested by the examination of a smear made from the growth in the tube and stained by

TABLE I.—Summary of Results in Confirmatory *Entercoccus* Tests

Kind of Specimen	Number of Samples	Tubes Positive				Agreement[1] (%)
		Presumptives	Confirmatory			
			Slant-Broth		Gram-Stain	
			No.	%		
Stored sewage, 0–60 days	150	1,000	858	85.8	852	99.3
Stored river water, 0–60 days	44	240	186	77.5	186	100.0
Fresh sewage	84	500	337	67.4	334	99.2
Fresh natural waters	54	260	237	91.2	236	99.6
Total	332	2,000	1,618	80.9	1,608	99.4

[1] Agreement of confirmatory slant-broth tubes and gram-stain specimens.

Gram's technique. The proof of a positive consisted of finding gram-positive, ovoid streptococci.

Results

A summary of the confirmatory test results is given in Table I. Of 1,618 tubes positive by "slant-broth" reading, 1,608(99.4 per cent) showed the presence of gram-positive, pleomorphic streptococci in the gram-stained smears. The disagreement between positives based on the tube reading (pin-point colonies on the agar slant plus turbidity of the broth) and the additional step of identification by the gram-stain smears was 0.6 per cent. Assuming no streptococcus was missed in the routine examination of 1,618 smears, this represents failure in 10 tubes, which in turn would increase the calculated M.P.N. by one tube in 10 tests out of 332 determinations. On the other hand, the time used in the preparation and microscopic examination of the gram-stains represents a marked reduction in the number of specimens that can be examined each day.

Summary

Elimination of the staining procedure in consideration of the above results would not change the M.P.N. of 322 samples examined. The combination of the three decimal dilutions used in calculating the M.P.N. of the remaining 10 samples would be increased by one positive tube in each instance, as two failures never occurred in the examination of the same sample. A difference of one positive tube is within the limits of reproducibility by the "Most Probable Number" method of planting serial dilutions.

The increased expenditure of time and material for the preparation of the gram-stained smears from the slant-broth culture tube is not warranted in sanitary surveys. The slight error introduced in approximately 3 per cent of the samples examined for the M.P.N. determination is without practical significance.

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STATISTICAL SUMMARY OF SEWAGE CHLORINATION PRACTICE IN THE UNITED STATES

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Introduction

The U. S. Public Health Service, through its Environmental Health Center at Cincinnati, Ohio, since 1939 has conducted and published an "Inventory of Water and Sewage Facilities in the United States" (1). This compilation of basic information is carried out in cooperation with the various State health departments. Grateful acknowledgment is due the engineering personnel of these organizations, who have effectively collaborated in promoting the success of this activity.

As part of the "Inventory," statistical summaries of sewage works practice are prepared, such as the recent general summary (2).

Data Included

The summary reported herein presents data on the practice of sewage chlorination, including the use of liquid chlorine or hypochlorite in connection with contact tanks. Data have not been arranged by point of application of the chlorine. Basic data are from the 1948 edition of the "Inventory" (unpublished).

In the Inventory, chlorination data are coded, through use of symbols and combinations, to show:

1. Chlorination—no detail as to use of hypochlorite or liquid chlorine, or existence of contact tanks.
2. Chlorination with contact tank—no detail on use of hypochlorite or liquid chlorine.
3. Chlorination with hypochlorite.
4. Chlorination with hypochlorite and contact tank.
5. Chlorination with liquid chlorine.
6. Chlorination with liquid chlorine and contact tank.

In entering this information on punch cards, the first two were coded by the same number. This summary, therefore, does not show all plants in which contact tanks are used.

Basic data of this paper are presented in Tables I, II, and III, in each of which the number of plants and the estimated population served by the various combinations of chlorination facilities are given. Table I is arranged by states; Table II, by community population groups based on the 1940 Census population of the community in which the plant is located; and Table III, by geographical areas as set up by the Census Bureau.

In Table IV, data are given showing plants with chlorination, arranged by degree of treatment, as well as comparable data on the total number of plants in each category. Table V presents comparable data for 1940, 1945, and 1948, showing the total number of plants and population served by chlorination facilities. Percentages of the total number of plants and population and the percentage change from 1940 to 1945, and from 1945 to 1948, are also given in Table V.

Discussion

The chlorination of sewage varies considerably from state to state. In general, chlorination is practiced most

Table I.—Number of Plants and Population Served by Various Methods of Chlorination—Arranged by States

State	No Detail in Inventory		Chlorination With								Total	
			Hypochlorite		Hypochlorite and Contact Tank		Liquid Chlorine		Liquid Chlorine and Contact Tank			
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served
Alabama	2	1,870	—	—	—	—	12	71,550	—	—	14	73,420
Arizona	2	2,800	—	—	—	—	3	125,840	—	—	5	128,640
Arkansas	—	—	—	—	—	—	6	17,250	1	9,000	7	26,250
California	30	130,125	—	—	—	—	23	841,195	1	41,000	54	1,012,320
Colorado	—	—	1	1,600	—	—	3	400,390	—	—	4	401,990
Connecticut	—	—	—	—	—	—	8	273,700	13	118,850	21	392,550
Delaware	4	9,110	—	—	—	—	6	11,965	1	3,000	11	24,075
Florida	1	1,345	—	—	—	—	9	186,800	12	48,600	22	236,745
Georgia	2	6,900	—	—	—	—	11	351,000	—	—	13	357,900
Idaho	1	700	—	—	—	—	2	6,600	2	7,500	5	14,800
Illinois	3	8,680	—	—	—	—	25	151,825	14	151,825	42	248,065
Indiana	1	450	—	—	—	—	10	244,900	3	1,200	14	246,550
Iowa	5	54,380	—	—	—	—	—	—	1	280	6	54,660
Kansas	—	—	—	—	—	—	1	2,000	—	—	1	2,000
Kentucky	5	4,350	1	1,200	—	—	21	117,225	2	4,850	29	127,625
Louisiana	—	—	—	—	—	—	—	—	—	—	—	—
Maine	—	—	1	1,400	—	—	—	—	—	—	1	1,400
Maryland	—	—	1	325	1	900	15	61,600	8	51,683	25	114,505
Massachusetts	2	149,600	—	—	—	—	6	245,300	1	2,100	9	397,000
Michigan	5	50,180	—	—	—	—	18	2,556,525	38	358,880	61	2,965,585
Minnesota	17	19,120	1	330	8	7,300	10	815,580	52	256,445	88	1,098,775
Mississippi	4	37,600	1	600	—	—	9	34,000	1	4,000	15	76,200
Missouri	2	9,960	2	3,500	—	—	7	26,300	5	4,055	16	43,865
Montana	—	—	—	—	—	—	1	300	1	290	2	590
Nebraska	—	—	—	—	—	—	1	235	—	—	1	235
Nevada	—	—	—	—	—	—	—	—	—	—	—	—
New Hampshire	3	1,200	—	—	—	—	1	4,000	—	—	4	5,200
New Jersey	112	1,029,675	—	—	—	—	11	95,130	20	184,620	143	1,309,425
New Mexico	—	—	—	—	—	—	—	—	—	—	—	—
New York	34	167,275	3	2,500	—	—	117	2,862,170	18	249,110	172	3,281,055
North Carolina	5	36,300	1	1,000	—	—	14	69,650	—	—	20	106,950
North Dakota	—	—	—	—	—	—	—	—	—	—	—	—
Ohio	28	1,474,275	1	600	—	—	18	291,660	—	—	47	1,766,535
Oklahoma	34	229,525	—	—	—	—	6	43,790	—	—	17	273,315
Oregon	—	—	2	1,050	1	120	11	36,600	12	41,850	26	79,620
Pennsylvania	24	211,585	7	8,650	3	24,100	44	458,775	37	272,925	115	976,035
Rhode Island	—	—	—	—	—	—	4	296,500	4	55,600	8	352,100
South Carolina	1	9,000	—	—	—	—	5	85,500	—	—	6	94,500
South Dakota	—	—	—	—	—	—	1	2,200	—	—	1	2,200
Tennessee	4	11,200	—	—	—	—	4	14,210	—	—	8	25,410
Texas	20	77,030	59	68,620	3	2,460	18	368,555	—	—	100	516,665
Utah	—	—	—	—	—	—	—	—	—	—	—	—
Vermont	—	—	—	—	—	—	1	8,100	1	300	2	8,400
Virginia	1	2,000	3	2,010	—	—	32	80,030	17	180,080	53	264,120
Washington	—	—	—	—	—	—	34	137,710	14	95,765	48	233,475
West Virginia	6	19,000	2	345	—	—	2	7,500	2	20,300	12	47,145
Wisconsin	—	—	1	200	—	—	26	529,440	28	106,430	55	636,070
Wyoming	3	4,150	—	—	—	—	1	8,600	—	—	4	12,750
Total	338	3,759,385	87	93,980	16	34,880	557	10,943,200	309	2,205,850	1,307	18,036,715

frequently in the more populous states. For example, New York and New Jersey have the largest number of plants with chlorination facilities, and New York and Michigan have the largest populations so served. Only 5 states and the District of Columbia have no plants with chlorination facilities.

In the Middle Atlantic States, including New York, New Jersey, and Pennsylvania, 61 per cent of the sewage treatment plants have chlorination facilities, and more than half of the population served by treatment is also served by chlorination.

The percentage of plants equipped with chlorination facilities increases

TABLE II.—Number of Plants and Population Served by Various Methods of Chlorination—Arranged by Population Groups

Population Group	No Detail in Inventory		Chlorination With								Total	
			Hypochlorite		Hypochlorite and Contact Tank		Liquid Chlorine		Liquid Chlorine and Contact Tank			
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served
Under 500	15	5,925	14	5,360	3	470	19	15,515	22	9,200	73	36,500
500— 1,000	45	28,220	25	11,710	5	3,350	58	46,005	38	24,750	171	114,035
1,000— 5,000	140	329,095	43	53,030	6	7,090	245	594,625	146	330,355	580	1,314,165
5,000— 10,000	74	489,120	4	22,650	—	—	72	459,575	36	214,575	186	1,186,340
10,000— 25,000	38	510,585	1	1,200	2	24,000	88	1,204,960	37	449,005	166	2,189,750
25,000— 50,000	9	219,420	—	—	—	—	29	1,110,000	22	533,500	60	1,862,920
50,000—100,000	6	141,920	—	—	—	—	15	978,570	3	196,900	24	1,317,390
Over 100,000	11	2,035,100	—	—	—	—	31	7,532,950	5	447,565	47	10,015,615
Total	338	3,759,385	87	93,980	16	34,880	557	10,943,200	309	2,205,850	1,307	18,036,715

TABLE III.—Number of Plants and Population Served by Various Methods of Chlorination—Arranged by Geographical Areas

Geographical Area	No Detail in Inventory		Chlorination With								Total	
			Hypochlorite		Hypochlorite and Contact Tank		Liquid Chlorine		Liquid Chlorine and Contact Tank			
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served
New England	5	150,800	1	1,400	—	—	20	827,600	19	176,850	45	1,156,650
Middle Atlantic	170	1,408,535	10	11,150	3	24,100	172	3,416,075	75	706,655	430	5,566,515
South Atlantic	20	83,655	7	3,980	1	900	94	854,045	40	303,660	162	1,245,940
East N. Central	37	1,533,585	2	800	—	—	97	3,774,350	83	554,070	219	5,862,805
East S. Central	15	55,020	2	1,800	—	—	46	236,985	3	8,850	66	302,655
West N. Central	24	83,460	3	3,880	8	7,300	20	846,315	58	260,780	113	1,201,735
West S. Central	31	306,555	59	68,620	3	2,460	30	429,595	1	9,000	124	816,230
Mountain	6	7,650	1	1,600	—	—	10	541,730	3	7,790	20	558,770
Pacific	30	130,125	2	1,050	1	120	68	1,015,505	27	178,615	128	1,325,415
Total	338	3,759,385	87	93,980	16	34,880	557	10,943,200	309	2,205,850	1,307	18,036,715

TABLE IV.—Number of Plants and Population Served by Chlorination Facilities—Arranged by Degree of Treatment

Plants	Minor Treatment		Primary Treatment		Intermediate Treatment		Secondary Treatment		All	
	No. of Plants	Est. Pop. Served (1000's)	No. of Plants	Est. Pop. Served (1000's)	No. of Plants	Est. Pop. Served (1000's)	No. of Plants	Est. Pop. Served (1000's)	No. of Plants	Est. Pop. Served (1000's)
Having chlorination	30	698	547	7,657	51	2,988	679	6,694	1,307	18,037
All plants	51	4,019	2,984	18,393	106	3,595	2,917	22,691	6,058	48,698
% of total having chlorination	58.8	17.4	18.3	41.6	48.1	83.1	23.3	29.5	21.6	37.0

TABLE V.—Comparison of Plants Having Chlorination and Population Served for 1940, 1945, and 1948

Year	Number of Plants	Est. Pop. Served (1000's)	Proportion of Total Having Chlorination (%)		Change (%)	
			Plants	Population	Plants	Population
1940	1,127	14,336	20.2	35.3		
					12.0	11.8
1945	1,262	16,029	21.8	34.2		
					3.6	12.5
1948	1,307	18,037	21.6	37.0		

with increasing size of the community. Only 13 per cent of plants in communities of less than 500 persons have chlorination, whereas between 35 and 40 per cent of the plants in communities of over 10,000 population have such facilities.

Comparative data for 1940, 1945, and 1948 show no general increase in chlorination practice as regards the percentages of total treatment plants and population served by all treatment plants. Although the number of plants and the population served by such facilities both have increased, so also have the total number of treatment plants and the population served thereby.

National totals, listed by the various combinations used in the Inventory to show chlorination of sewage, are as follows:

Type of Chlorination	Number of Plants	Est. Pop. Served (1,000's)
No detail, or contact tank only listed	338	3,759
Hypochlorite	87	94
Hypochlorite and contact tank	16	35
Liquid chlorine	557	11,942
Liquid chlorine and contact tank	309	2,206

Whether liquid chlorine or hypochlorite is used has been omitted in so many cases that a firm analysis of the figures is not possible. It is expected, however, that when details become available for this group, the division will be along much the same lines as is currently indicated for the four groups where details are available. These show that liquid chlorine is used in the majority of installations, and that the major portion of the population is not served by chlorination facilities incorporating contact tanks. Hypochlorite is used in only 103 installations serving less than 130,000 persons, its use being confined to plants in communities of less than 25,000 population.

Summary

Statistical data from the 1948 Inventory of Water and Sewage Facilities in the United States are presented showing sewage chlorination practice. Number of plants and population served for various types of chlorination facilities are arranged by States, community population groups, and geographical areas. Approximately 1,300 plants serving more than 18,000,000 persons chlorinate sewage at some point in the treatment process. Such facilities are most common in the more populous States and in plants serving cities of over 10,000 population. Comparative data for 1940, 1945, and 1948 indicate no general increase in the frequency of chlorination practice.

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INFLUENCE OF VELOCITY ON SULFIDE GENERATION IN SEWERS

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In a 1946 paper, Pomeroy and Bowlus (1) discussed the influence of velocity on sulfide build-up in sewage. A tabulation was given of the velocities necessary to prevent the build-up of sulfides in flowing sewage corresponding to different values of the "effective B.O.D." of the sewage. The tabulated values agree with the relationship

$$V = 0.137 \text{ (Effective B.O.D.)}^{0.496} \quad (1)$$

in which "effective B.O.D." is defined as (measured B.O.D.)(1.07^{t-20}), t being the temperature of the sewage in ° C. Pomeroy and Bowlus do not claim that the relationship given by them is rigidly true under all conditions, as the B.O.D. alone is not an adequate measure of the influence of the sewage "strength" in the sulfide production process.

The writer has realized the great value, to engineers engaged in sewer design, of a reliable relationship of the type developed by Pomeroy and Bowlus. It was felt, however, that before accepting the relationship suggested by them, it would be desirable to carry out investigations under the conditions applying to the local Melbourne system and at the same time to attempt to improve, if possible, the form of the relationship between the various factors involved. If the theory can be accepted, in general principle, that sulfides generated on the sewer wall are partly or wholly oxidized by oxygen absorbed at the sewage surface, then the factors involved appear to be those influencing the rate of absorption of oxygen at the sewage-air interface and those determining the relative strengths of the sulfides and the other constituents of the sewage as competitors for this absorbed oxygen.

Development of Relationship

The purpose of this paper is to present a form of relationship incorporating the factors connected with surface absorption of oxygen in a somewhat more rational manner than that proposed by Pomeroy and Bowlus. No attempt has been made to substitute a more suitable term for the B.O.D., it being assumed that, whatever the proper measure of competing strength of sewage for absorbed oxygen may be, this measure is proportional to the B.O.D. This assumption is, probably, reasonably near the truth except, perhaps, for sewages containing certain industrial wastes or previously subjected to detention in pressure mains.

In the development that follows, the influence of temperature has been taken on the same basis as used by Pomeroy and Bowlus, but two separate terms, B.O.D. and $f(T)$, have been introduced instead of combining these in the expression "effective B.O.D." This has been done because it is felt that at some future date the influence of temperature as expressed by the term $f(T)$ may require further elucidation, as the temperature influences component processes additional to the "bacterial activity" referred to in the paper previously mentioned.

The analyses of the results obtained by Streeter, Wright, and Kehr (2) from experiments on oxygen absorption into clean flowing water, and by the experiments reported herein on the evolution rate of sulfide gas from flow-

ing sewage, indicate that rate of gas absorption into, or evolution from, a flowing liquid can be expressed fairly accurately in terms of a power of the Reynolds number, N_{Re}, of the liquid flow. Although other factors enter the relationship, the most significant one appears to be this Reynolds number.

The rate of oxygen absorption per unit area of sewage surface per hour per unit of oxygen partial pressure potential, K_G, may be expressed, therefore, in terms of the Reynolds number by

$$K_G = C_1(N_{Re})^n \qquad (2)$$

in which the constant, C_1, depends on the system of units used and the concentration of oxygen in the atmosphere above the sewage. From the analyses referred to, the value of n is approximately unity.

For a sewage flow of surface width b perpendicular to the direction of flow and of cross-sectional area A, the rate of oxygen absorption per unit length of sewer, O_T, expressed in p.p.m. of sewage per hour, would be given by

$$O_T = C_2\frac{b}{A}(N_{Re})^n \qquad (3)$$

in which C_2 is a constant.

This absorbed oxygen would be divided between the sulfides and the other oxygen absorbing constituents of the sewage in proportion to their respective instantaneous rates of demand. If these demand rates are assumed to be proportional to the amounts of sulfide, S, and B.O.D., respectively, available for oxidation, and if the amount of oxygen absorbed by sulfides is small compared with that absorbed by other constituents of sewage,

$$O_s = \frac{C_3 S}{C_4(\text{B.O.D.})}(O_T) \qquad (4)$$

in which O_s is the rate of oxygen absorption by sulfides, and C_3 and C_4 are constants of proportionality.

It is important to note that the amount of sulfide referred to in Eq. 4 as being available for oxidation includes that portion generated and oxidized, and, therefore, not revealed in normal tests for sulfides, as well as the portion remaining in the unoxidized state. To keep a stream of sewage free from unoxidized sulfide, and, therefore, prevent evolution of corrosive gas to the sewer atmosphere, it is necessary that the rate of oxidation of sulfides shall continuously equal their rate of generation and that there shall, at this time, be no excess of unoxidized sulfides left in the sewage when it enters the section of sewer under consideration. Under these conditions,

$$O_s = C_3 S$$

and

$$C_4(\text{B.O.D.}) = O_T = C_2\frac{b}{A}(N_{Re})^n \qquad (5)$$

or

$$N_{Re} = \left[\frac{C_4}{C_2}\frac{A}{b}(\text{B.O.D.})\right]^{1/n} = C\left[\frac{A}{b}(\text{B.O.D.})\right]^{1/n} \qquad (6)$$

in which N_{Re} is now the Reynolds number required to just prevent sulfide build-up under the conditions of B.O.D., A, and b are the values applying at the site under consideration, and C is a constant. Eq. 6 would only apply when sewage entering the section is free from unoxidized sulfide. If unoxidized sulfide were present, the proportion of the total available oxygen absorbed by sulfides would be increased and excess unoxidized sulfide would gradually disappear. On the other hand, the sulfide build-up rates applying where sewage contained free unoxidized sulfide would be less than for the same sewage when unoxidized sulfide was absent.

The foregoing development applies for the particular temperature existing in the sewage at the time under consideration. For the correlation of results obtained from experiments conducted at different temperatures, it is

necessary to allow for the influence of temperature. This can best be done by the adjustment of all results to those values which would have applied at one convenient standard temperature, say 20° C. Assuming that the rate of generation of sulfides is proportional to $f(T)$, it follows that

$$S_{20} = \frac{S}{f(T)}$$

in which S is the amount of sulfide available for oxidation at the temperature of the experiment, S_{20} is the amount of sulfide that would have been available at 20° C, and, following Pomeroy and Bowlus, $f(T)$ is assumed to be $1.07^{(t-20)}$.

To enable the experimental results to be brought to a comparable temperature basis, S_{20} should be substituted for S in Eq. 4, permitting Eq. 6 to be rewritten:

$$(N_{Re})_{20} = C\left[\frac{A}{b}(\text{B.O.D.})f(T)\right]^{1/n} \qquad (7)$$

in which it is noted that the expression (B.O.D.) $f(T)$ corresponds to the "effective B.O.D." of Pomeroy and Bowlus.

Experimental Confirmation

To confirm whether the relationship developed in the foregoing discussion applied under actual local sewer conditions, observations were made in a number of sewers. The following routine was employed:

1. A sewer was selected in which it was known that, during the period of low night flow, no sulfides were present, but in which sulfides regularly occurred during periods of higher flow. Care was taken to select observation points so that, for a considerable distance upstream, the sewer gradient was uniform and no large tributaries entered.

2. Starting before sulfides were present in the sewage, samples were taken continuously until they indicated the first trace of sulfide, the chemical tests being carried out at the sampling manhole. The portion of sample not used for the sulfide test was retained for B.O.D. and other determinations.

3. As soon as sulfide was observed, the velocity of the sewage was determined by observing time of travel, through a known length of sewer, of dye tipped into the sewage.

4. Measurements were also taken of sewage depth at the time of the first appearance of sulfide and of the sewer diameter. Results of the observations are given in Table I.

In practice it was often found that sulfides first appeared during a period of rapidly increasing B.O.D. and velocity; therefore, results as tabulated are subjected to some error, generally small, due to the fact that the B.O.D. and velocity measured may not exactly coincide with those applying at the instant of first sulfide appearance.

To test the application of Eq. 7 to actual local sewer conditions, the values of $\frac{A}{b}$ (B.O.D.) $f(T)$ were plotted against corresponding values of N_{Re}, using logarithmic scales (Figure 1). If the equation is valid, this plot should be a straight line whose slope would give the value of the exponent, $\frac{1}{n}$. With the exception of points 3, 6, 7, and 10, the points do fall reasonably close to a straight line, the equation of which is

$$N_{Re} = 5{,}700\frac{A}{b}(\text{B.O.D.})f(T)^{0.89} \qquad (8)$$

in which A and b are measured in square feet and feet, respectively.

It is to be noted that the value of 1.12 (that is, the reciprocal of 0.89) derived for n from the above equation, is somewhat higher than the approximate value of 1.00 obtained, as previously stated, for gas evolution or absorption. This difference may well be accounted for by the fact, mentioned by Pomeroy and Bowlus, that increased velocity or, in this development, increased Reyn-

TABLE I.—Observed Data on Sulfide Generation in Melbourne, Australia, Sewers

Observation No.	Sewer		Sewage								
	Location	Dia. (in.)	Depth of Flow (in.)	Velocity (ft./sec.)	Temp. (° F.)	$f(T)$	$N_R \times 10^{-4}$	B.O.D. (p.p.m.)	Flow Area, A (sq. ft.)	Surface Width, b (ft.)	B.O.D. $\times \frac{A}{b} f(T)$
1	Braeside Outfall	30	9.0	1.35	56	0.64	0.172	115	1.13	2.24	36.8
2	South Yarra Main, Prahran	54×40[1]	24.2	3.40	58	0.69	0.781	267	3.66	2.75	243.8
3	North Yarra Main, Heidelberg[2]	24	7.0	1.24	57	0.66	0.110	208	0.56	1.69	45.3
4	South Yarra Main, Prahran	54×40[1]	19.9	3.24	58	0.69	0.659	237	2.74	2.54	175.6
5	Braeside Outfall	30	8.8	1.37	59	0.71	0.185	134	1.16	2.26	49.2
6	Braeside Outfall[3]	30	6.0	0.97	59	0.71	0.094	54	0.68	1.99	13.2
7	Hobson's Bay Main, Bay St.[4]	40×28[1]	18.9	2.05	67	0.96	0.492	308	3.17	2.29	411.1
8	Beach Rd. Main, Mordialloc	21	2.1	1.10	62	0.80	0.039	100	0.12	1.03	9.1
9	North Yarra Main, Heidelberg	48	12.3	2.23	65	0.89	0.328	225	0.12	1.83	127.3
10	North Yarra Main, Dynon Rd.[5]	93	34.0	2.91	64	0.86	1.615	483	16.17	7.50	895.6
11	Point Nepean Rd. Main, White St., Mentone	18	4.6	1.77	64	0.86	0.136	168	0.35	1.30	38.5
12	West Caulfield Branch	15	6.5	3.10	67	0.96	0.320	214	0.51	1.24	84.8
13	North Road Branch	18	11.4	3.06	65	0.89	0.455	212	1.13	1.46	146.9

[1] Ovoid.
[2] Rain on test day.
[3] Taken on falling flow.
[4] Prior wet periods.
[5] Rain prior to test.

olds number, would be likely to reduce the amount of wall film or its sulfide generating power. The fluid shear acting on wall slime is also a function of the Reynolds number applying.

The probable explanations for the divergence of points 3, 6, 7, and 10 from the general line are:

Point 7.—Heavy rain had fallen in Melbourne over a period of six to eight weeks prior to the experimental observations. Although the Melbourne sewerage scheme is designed as a separate system, a considerable proportion of each rain enters the sewers. It has been observed repeatedly that for a considerable time after rain the generation of sulfides is reduced, and this reduction persists for a period, even after the flow and B.O.D. have returned to normal.

Other data available at this sampling point indicate that the appearance of the sulfide usually first occurs about 1 hr. earlier than on the day on which the observations were taken. At this time, the B.O.D. is greatly reduced and the Reynolds number is somewhat lower than indicated by the values in Table I. The available data indicate that with dry weather conditions preceding the experiment the plotted point would have approximately conformed to the general line shown.

Points 3 and 10.—Observations were taken after heavy rain on preceding days. The displacement of the points from the general line is probably, therefore, again due to the inhibiting effect of prior rain on sulfide generation. Owing to continued wet weather, there was not opportunity to confirm this by new observations under dry-weather conditions.

Point 6.—Contrary to the procedure applying to other tests, observations

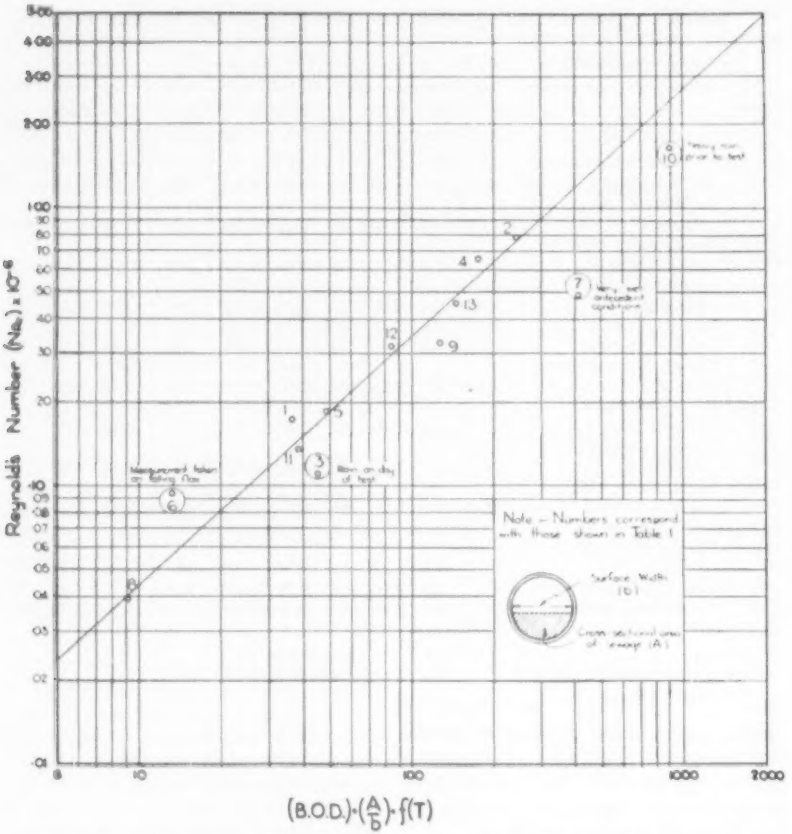
Reynolds Number (Ne) x 10⁻⁶
(B.O.D.)·(A/D)·f(T)
Note – Numbers correspond with those shown in Table I
Surface Width (D)
Cross sectional area of sewage (A)

FIGURE 1.—Relation of Reynolds number to observed B.O.D. and the physical characteristics of the sewer.

were made during a period of falling flow and decreasing B.O.D. For the test to indicate no unoxidized sulfide would require that the surface aeration of the stream was capable of oxidizing not only all the sulfide as it was generated, but also the residuals of the unoxidized sulfide remaining from the prior period. At the time of disappearance of unoxidized sulfide from the sewage, the values of B.O.D. and Reynolds number would be lower than those to be anticipated from observations on rising flow and increasing B.O.D. Consequently, point 6 should plot above the general line.

Conclusions

The results of the work described herein indicate a promising possibility that conditions necessary for no build-up of sulfides in the sewage flow during dry weather can be approximately stated in terms of the Reynolds number, the B.O.D., the temperature, and the geometry of the sewage cross-section. It is appreciated that many other factors enter the problem and that, for the final general solution, these must be investigated. Perhaps a first major step should be the substitution for B.O.D. of some more suitable meas-

ure of the oxygen reducing power of the sewage relative to that of the sulfides.

It is difficult, from the sewers available to any one sewerage authority, to select sufficiently to give a wide range of sizes, shapes, velocities, B.O.D.'s, and temperatures. Additional experimental data such as given in Table I, particularly with respect to large sewers, is necessary in order that the usefulness of the suggested type of formulation may be confirmed, or modified to satisfy the extended data more closely.

Acknowledgments

All of the chemical tests involved in this study were made by the staff of, and under the supervision of, the Board's senior chemist and bacteriologist, C. D. Parker, who also suggested use of the period of rising flow to determine the conditions necessary for no sulfide build-up.

Acknowledgment is made also of the assistance given by E. J. S. Batten, assistant engineer, in the analysis of the test results.

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MUNICIPAL GARBAGE DISPOSAL BY HOUSEHOLD GRINDERS AT JASPER, INDIANA *

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Can a municipality dispose of garbage with home grinders? Local, financial, and engineering problems must be considered and solved before this question can be answered. This paper briefly discusses these problems, using as a concrete example the city of Jasper, Ind., which is in the process of completing such a program.

A comparison study of various methods of garbage disposal was made before Jasper selected the home grinder method. The aesthetic advantages to be gained through the elimination of the garbage can, with its attraction to flies, rodents, etc., were considered; however, the final decision to use home grinders was based largely on economic considerations.

Another important consideration is the type and characteristics of the local populace. It is doubted if this method of garbage disposal could be effectively used in a run-down neighborhood, a city where there was little pride in the general municipality or where the inhabitants were chiefly tenants and not property owners. On the other hand, if the inhabitants are thrifty, hardworking people who have a distinct civic pride and who own their own homes, this method of garbage disposal should be very satisfactory.

Table I illustrates the highlights of a cost tabulation for garbage disposal studies at Jasper, Ind. It will be noted that four methods were compared; namely, the use of individual grinders for each home, central grinding and treatment at the sewage treatment plant, the sanitary fill method, and the existing farm contract method. Due to a past outbreak of disease to garbage-fed hogs, and also due to the fact that a future farm contract will be almost impossible to obtain, the first three methods only were considered. By disregarding the farm contract method, the cost of the home grinder method of garbage disposal in Jasper is only slightly higher per family per month than either of the other methods studied. In a similar analysis made later by local authorities, who assumed that the cost of enlarging the sewage treatment plant to handle the additional load should not be considered as part of the cost of garbage disposal, the home grinder method showed a lower monthly cost per family than either of the two remaining methods.

Incineration was not considered in this particular instance, due to the fact that a sewage treatment plant had to be built and the initial cost of adding the garbage load to the sewage treatment plant would be obviously much lower than the construction of a separate incineration plant to handle the garbage alone.

Based on enlargement of the data of Table I, the individual home grinder method was decided to be the most economical to use at Jasper.

Effect on Plant Design

There is little doubt that the local sewer system in practically all municipalities will handle the additional gar-

* Presented at 1950 Annual Meeting, Central States Sewage Works Assn.; Indianapolis, Ind.; June 9–10, 1950.

TABLE I.—Cost Comparison of Garbage Disposal Methods for Jasper, Ind.

Cost Item	Method			
	Home Grinders	Central Grinding	Sanitary Fill	Farm Contract
Original Investment	$122,500[1]	$43,000[2]	$27,000[3]	None
Annual amortization cost[4]	5,305	1,862	1,170	—
Annual cost of labor	None	6,600[5]	6,600[5]	—
Annual depreciation (plant)	1,500[6]	1,400[6]	—	—
Annual depreciation (equip.)	—	800	1,000	—
Maintenance of equipment	5,000[7]	480	960	—
Operation (gas, oil, etc.)	—	600	1,200	—
Annual cost	$11,805	$11,742	$10,930	$5,000
Monthly cost per family	$0.66	$0.65	$0.61	$0.28

[1] $40,000 treatment plant increase plus $82,500 for grinders installed.
[2] $35,000 treatment plant increase plus $8,000 for garbage truck.
[3] $8,000 for garbage truck plus $15,000 for excavating machinery and $4,000 for land.
[4] Based on 3 per cent over 40-yr. period.
[5] One man at $200 per month plus 2 men at $175 per month.
[6] Based on treatment plant increase only.
[7] One full-time man at $3,000 plus $2,000 for repair parts.

bage load. Published results of several authoritative tests prove that sewers of standard sizes laid at standard minimum gradients will satisfactorily carry garbage grindings with the normal sewage flow. The important consideration is the adequacy of the treatment facilities.

A new sewage treatment plant designed for Jasper originally did not contemplate the treatment of garbage, as the city had a good garbage contract at that time. The garbage problem arose after the completion of the treatment plant plans, which had to be revised to provide for the additional garbage load. Briefly, this was done by increasing the aeration capacity by 50 per cent, the digestion capacity by approximately 70 per cent, and the sludge drying beds by about 60 per cent. No change was made in the primary or secondary settling tanks, as the increase in volume of liquid is very minor. The problem of providing adequate treatment facilities to handle the additional load of ground garbage is one of the utmost importance. However, the factors of increase used at Jasper are not to be construed as overall recommendations for every municipality, as too many varying conditions may exist.

Local Procedure

Once it is determined that, in a particular municipality, it is economically feasible to dispose of garbage with home grinders, how does the municipality proceed? It is not possible to force a garbage grinder into every home. It is, however, possible to pass an ordinance making it necessary for each home owner to provide his own garbage disposal facilities, and then make it attractive for the owner to purchase and install a garbage grinder in his home. This was the method followed in Jasper. Such an ordinance must be thoroughly enforced, or a generally unsanitary condition may prevail if there are a number of home owners who do not adequately dispose of their garbage and who will not install a garbage grinder.

The financing of such a venture is of interest. At Jasper, it was originally contemplated that the garbage

disposers would be purchased with funds from either a separate revenue bond issue or as part of the sewage treatment plant revenue bond issue. To make such financing possible, a special emergency bill was passed through the 1949 State Legislature. The bill provides enabling legislation and permits the issuance of revenue bonds for the purpose of installing individual food waste disposers in private homes. The important feature of the bill is that it provides the municipal authority to establish such a project. It reads in part as follows:

"SECTION 1. That every city or town in the State of Indiana now or hereafter owning, operating and maintaining, or hereafter having under construction, a sewage treatment works under the authority of and pursuant to Chapter 61 of the Acts of the General Assembly of the State of Indiana for the year 1932, and all acts amendatory thereof or supplemental thereto, shall have power to acquire, install, equip, own, operate and maintain within or without the corporate limits of such city or town a garbage disposal system consisting of garbage grinders to be installed in private residences, business places or any other building within or without the city or town, with the consent of the owners and tenants thereof, and all other appurtenances necessary or useful and convenient for the grinding of garbage into sewage and disposing of the same through the sewer system of such city or town, and to issue revenue bonds to pay the cost of the necessary equipment installation thereof. No obligation shall be incurred by the municipality for the cost of such equipment and the installation thereof except such as is payable solely from the funds provided under authority of this act."

The act is available for the use of any municipality in the State of Indiana. Although the bill was sponsored by Jasper, its provisions for revenue bond financing were not followed because a vote of the people indicated a preference to finance the installation of the grinders without the use of revenue bonds. The bill was used as authority to establish such a project, with no obligation to the municipality. Actually, in Jasper, the city acted as a purchasing agent for the home owners and was able to obtain a very low complete installation cost, due to the volume of units being purchased. The grinders are being paid for by the individual home owners at a price received by the city under open competitive bidding. In most cases, the grinders are being purchased on a cash basis. Local banks have arranged financing in those cases where the owner is unable to pay the required $75.00 at one time. A trust fund was established. The home owners pay the trust fund, from which the contractor is paid as his work progresses. The city itself has no financial obligation.

The following illustrates a typical application and contract, as used by Jasper, for a garbage grinder unit:

The "Rules and Regulations" referred to are printed on the back of the Application and Contract form, as follows:

RULES AND REGULATIONS

The rules and regulations will be in force from the time the installation of the grinding unit is made, and shall remain in force until the contract has been revoked through cause or written request for discontinuance of the service is filed by the owner or tenant.

All applications for garbage or food grinder service shall be made at the City Office in accordance with Section 10, Chapter 87, of the Acts of the 1949, General Assembly of the State of Indiana.

For the safety of the owner or tenant, the City of Jasper reserves the right to inspect all installations before the grinding unit is placed into operation, and reserves the right to reject any work not in accordance with the City's Rules and Regulations and those of underwriters and manufacturers. But the City will not, after the first year of use, assume any responsibility or loss due to defects which may arise in wiring, plumbing or the installation thereof.

All electrical or water service connections to be made to the grinding units shall

APPLICATION AND CONTRACT

Jasper, Indiana

———————, 19——

The undersigned, ———————, and ———————,
(Owner) (Tenant)
of Jasper, Indiana, hereby make application (in accordance with Section 10, Chapter 87, Acts of 1949), to the Board of Public Works and Safety of the City of Jasper, Indiana, for the purchase and installation of a garbage or food waste grinding unit, to be installed in the residence at ——————— Street, Jasper, Indiana, which installation shall be in accordance with and subject to the Rules and Regulations, which are set out herewith and made a part of this contract.

I, or we, hereby agree to make full payment to the City of Jasper for the purchase and installation of such grinding unit of Seventy-five ($75.00) Dollars, upon the following terms:

(Use No. 1 or No. 2 and strike other out.)

1. $——————— with application and (Min. $2.00) balance of $ ——————— on day of installation.
2. $75.00 with application.

BOARD OF PUBLIC WORKS AND SAFETY
OF THE CITY OF JASPER, INDIANA

By ———————————
(City of Jasper)

———————————
(Owner)

———————————
(Tenant)

---

be in conformity with the provisions of pertinent City ordinances, and any and all rules and regulations which may be made with reference to the installation of such grinding units.

In the installation of the grinding unit, the authorized representative of the city shall have the authority to cut out the sink opening in cases where the present sink opening is not large enough for proper grinder installation, with the understanding that the manufacturer guarantees not to damage the sink and to make proper replacement of the sink if damage is caused by such sink boring.

Any authorized representative of the City shall have the right to enter upon the premises of the owner or tenant at all reasonable times, for the purpose of making installation and for the inspection of the grinding unit so installed, and also to disconnect service wires or water supply for any of the following reasons:

First: For repairs;

Second: For want of supply of current or water;

Third: For violation of any of these rules.

The City of Jasper agrees to use reasonable diligence in providing a regular and uninterrupeted supply of electrical current and water, but in case the supply of current or water should be interrupted or fail by reason of accident, legal process, state or municipal interference, for strikes, for the purpose of making repairs or changes in the machines, the City shall not be liable for damages for such interruption or failure.

The food waste and garbage grinders installed under the contract made for the original purchase of the same will be guaranteed for one year by the manufacturers against all defects of workmanship and defects of installation, except any damage which may be caused by the owner, tenant or user thereof by placing therein other than food or garbage wastes. Thereafter, the users of such units shall be responsible for any damages thereto and the cost of repair or replacement, ordinary wear and tear included.

The food waste and garbage grinder purchased and installed under this contract shall be installed only at the property described in the contract and is not offered for the purpose of resale by the owner or tenant.

Specification Problems

The preparation of a set of specifications for the purchase and installation of garbage grinders on a municipal basis was unique; no precedent had ever been established as to how bids should be taken on this type of contract. The specifications were actually written with considerable leeway, making it possible for any garbage grinder manufacturer to bid, provided he could demonstrate sufficient previous manufacturing experience and performance of his grinder. Bids were to be submitted on either a "completely installed" or a "furnish only" basis.

The cutting of different types of sinks to adapt the garbage grinders created quite a problem. In Jasper, about 60 per cent of the sinks had an opening too small to receive grinders. Consequently, provisions had to be made for either boring or replacing these sinks. These items were covered as special unit prices in the original bid forms and could be quoted on or omitted by the bidders.

The special tool being used by the successful bidder to bore the sink openings to the required size is basically composed of a clamp, which clamps below and above the sink, and a motor operated, rotating cutter, which cuts into the sink by means of exerting hand pressure on a vertical screw. To date this machine is doing a very excellent job of cutting practically all types of sinks encountered (Figure 1).

Special precaution was taken in the specifications to cover the reaming of the waste line between the sink and the main house sewer. This waste line had to be reamed with a cutting tool, such as a "Roto Rooter" or equal, and could not be rodded only. Experience has indicated that this is very important to a proper installation.

FIGURE 1.—Before, during, and after stages of sink boring process.

Bids and Contract Award

Table II illustrates the highlights of the final tabulation of bids received. The bidders are designated by number, the names being purposely omitted.

The bid price for the grinders varied from $35.19 to $52.70 without water interlocks, and from $39.69 to $59.55 with them. Only two manufacturers bid on the units completely installed, including the necessary boring or replacement of any sinks, as well as the electrical connections required. The price varied from $68.67 to $95.00 per unit for complete installation of the grinders only, and from $74.17 to $100.50 per unit for complete installation of the grinders and interlocks.

The contract was awarded to bidder No. 5, who quoted on the units complete with water interlocks and included entire installation, reboring of sinks, and all electrical work required at a price of $74.17. Comparison of this cost with the retail cost of approximately $120.00 per unit, plus possibly $30.00 per unit for installation, shows the considerable saving brought to home owners by the Jasper plan.

The original garbage farm contract was paid for at a general tax rate of 17½¢ per $100. If the city were to handle its own garbage collection, the tax rate would have to be 35¢ per $100. At an average assessed evaluation of $2,000, the annual cost per user would be $7.00 This means that the home

TABLE II.—Unit Bid Prices (in Dollars) for Individual Food Waste Disposers, Jasper, Ind.

Item	Bidder					
	1	2	3	4	5	6
Furnish—Grinder only	—	48.00	52.70	50.78	35.19	—
Furnish—Grinder and interlock	—	56.00	59.55	56.03	39.69	—
Grinder only—Installed[1]	—	—	—	—	68.67	95.00
Grinder and interlock—Installed[1]	77.85	—	—	—	74.17	100.50

[1] Includes boring of sinks and all electrical wiring.

units pay for themselves in less than 11 years if interest on the investment is not considered. The unseen benefits in general convenience, rat control, fly and mosquito control, etc., cannot be evaluated, but should be considered.

Tests of Units

It was decided that some type of unprejudiced and uniform test should be established and conducted for each grinder submitted. Manufacturers have their own methods of conducting exhibition tests, but the engineers felt that a uniform test was required for comparison purposes. Therefore, two tests were conducted—a dry run comparison and a composite sample comparison. Tests were made on only 5 units, as bidder No. 6 quoted on the same machine as one of the other five.

Dry Run Comparison

The main purpose of the dry run comparison test was to determine whether or not a water interlock was required on all grinders, or only on some makes of grinders. There is a great deal of discrepancy in the claims of the different manufacturers. In explanation, the water interlock is a flow-type switch inserted in the cold-water line and wired in series with the sink switch so that a given volume of water must be flowing in the cold-water line before the unit will operate. It was felt that if a grinder, when operating dry, would retain the grindings in the machine casing, a water interlock might not be required. However, if the grindings were forced into the sewer and were not retained within the casing of the machine, a water interlock probably would be required in order to immediately flush the grindings away. Past experience records indicate that many maintenance problems arose in the water interlocks. If they could be safely omitted a good portion of maintenance cost might be saved.

The dry run comparison test consisted of inserting 1 lb. of green beans in each machine, running the machine for 1 min., and catching the grindings. The amount of material passed by the machine when operating dry was weighed, and the weight compared with the original 1-lb. sample. The results (Table III) indicate that the amount of dry material passed varied from 3 to 22 per cent. The grinder that passed 22 per cent of the dry material might require an interlock, whereas the machine that only passed 3 per cent of the dry material might not require an interlock, if the relationship between speed of grinding and volume

TABLE III.—Dry Run Comparison Test on Individual Food Waste Disposers, Jasper, Ind.

Amount Passed in 1 Minute[1]	Bidder				
	1	2	3	4	5
Weight (oz.)	3	3.5	0.5	1.5	1
Portion (%)	18.7	22	3	9.4	6

[1] Sample consisted of 1 lb. of green beans, ground dry.

FIGURE 2.—Amount of material passed by each grinder during 1-min. dry run test.

of water be disregarded. Figure 2, which shows the grindings as passed during the test, illustrates the variation in the amount of material passed by the five different machines when no water was used.

It would seem that water interlocks, when applied on a municipal basis, are very desirable as a safety measure, particularly if the municipality is assuming the responsibility for maintenance of the units. It is deemed very important that the speed of grinding and the amount of water used be synchronized. The water interlock helps to accomplish this result, which may offset the additional maintenance likely to arise.

Composite Sample Comparison

In a second test on each of the units, each manufacturer was provided with an identical composite sample of food waste and required to put it through his machine in a period of 1 min., each with an equal flow of water. The grindings from each machine were then collected, as were the unground portions left in the grinder, and a comparison was made between the grindings of the various machines tested. It should be noted that this was strictly a comparison test only.

The composite sample included a large variety of food wastes that might normally be put through a food waste disposer, plus some items that might drop into a sink accidentally. The sample consisted of the following:

1½ oz. lettuce
1½ oz. corn cob (raw)
5 oz. green beans
½ oz. corn husks
grape vines
2 oz. carrot tops
1 stalk celery
1 banana peel
1 oz. radish tops
2 black walnuts
3½ oz. cabbage leaves (raw)
4 grapes
3 marshmallows
4 oz. raw beef and gristle
4 oz. uncooked bone
1 chicken head
1 chicken thigh
1 piece gristle
1 poultry foot
1 chicken neck
1 oz. bacon rind
1 brazil nut
1 oz. cheese rind
2 egg shells
1 safety pin
1 pc. chewing (bubble) gum
3 milk bottle caps
2 oz. piece of soap
1 plastic button
1 rubber band
6-in. piece store string
6 × 12-in. piece heavy paper
1 paper napkin
3 metal bottle caps
2 match sticks
1 pkg. paper matches and cover

It will be noted that the composite sample contained some items which cannot be handled by any garbage grinder. The purpose of including such items as metal bottle caps, etc., was not to determine whether the grinder would dispose of these items, but to determine whether they would jam a machine and make dismantling necessary to restore it to service. The results of the test (Table IV) indicate that this happened in the case of two machines; one machine jammed twice on metal bottle caps and another on

TABLE IV.—Composite Sample Comparison Test on Individual Food Waste Disposer, Jasper, Ind.

Factor	Bidder				
	1	2	3	4	5
Weight of composite sample (oz.)	37	37	37	37	37
Weight of portion not ground (oz.)	15	12	19.5	27	15
Portion not ground (%)	40	32	53	73	40
Jamming on metal pieces	None	None	Once[1]	Twice[2]	None

[1] On black walnut. [2] On metal bottle cap.

FIGURE 3.—Amount and nature of material passed in 1 min. using composite sample and same quantity water.

a black walnut. The remaining machines did not pass either of these items, but did not jam.

Table IV also shows the weight and percentage of the portion of the complete sample which was not ground by the machine. It will be noted that the percentage not ground varied from 32 to 73 per cent. Figure 3 shows the amount of material, as well as the character of the ground particles, passed through each of the five machines tested. Figure 4 shows the amount and character of the material which did not pass through the machines.

Summary

It is now possible for a municipality to consider disposing of its garbage by the household grinder method because:

1. In Indiana, at least, the law provides authority for carrying out such a municipal public improvement project, and also provides a method of financing.

2. There are at least 7 different manufacturers, and twice that number of sales organizations, anxious to sell and ready to bid competitively on furnishing the appliances.

FIGURE 4.—Amount and nature of material not passed during composite sample test.

3. Devices have been developed to satisfactorily cut practically any known kind of sink material, thereby assuring the possibility of complete installation on a city-wide basis.

It may be generally said that a municipality can satisfactorily dispose of garbage with home grinders if:

1. Its sewers conform with the accepted standards for sanitary sewers.

2. Its sewage treatment facilities are adequate or provisions for expansion are provided.

3. Its population is progressive and financially able to support any type of garbage disposal facilities.

MUNICIPAL USE OF SYNTHETIC DETERGENTS

The use of synthetic detergents has increased considerably since World War II, being extended even to cleaning of city streets. In an interesting commentary on this phase of detergent use in the United States, Camus (1) notes that arylalkyl-sulfonates have decided advantages over other street degreasing compounds because they are soluble in cold water, are unaffected by hardness of the water, and are particularly satisfactory as wetting and emulsifying agents.

The dangerous skid-provoking film resulting from oil and grease drippings from motor vehicles necessitates removal of this residue from the roadways. Soap has proved inadequate, as it leaves soapy films, which are in themselves skid-provoking; dissolves slowly in cold water; gives insoluble salts when used with hard water; and requires relatively large quantities.

Removal of the oils and fatty matters from the roadway by arylalkyl-sulfonates also removes a considerable quantity of the dust bound in by the oil film. Camus further states that the dust removal, together with the aseptic effect of distributing the arylalkyl-sulfonates with their bactericidal properties, has been reported to sensibly reduce the influenza and common cold epidemics in cities where the compounds have been used.

To those concerned with sewage works, Camus' discussion may open the door to a new phase of the synthetic detergent problem. For example, combined sewerage systems, particularly if connected to a treatment plant, may instigate all the troubles inherent with large usage of detergents if local street departments clean with these products and flush the resultant wastes and drainage to catch basins. Close coordination of street cleaning with treatment plant operation may be necessary to offset the undesirable results.

Reference

1. Camus, A., "Applications des Detergents Synthetiques dans les Techniques Urbaines." *L'Eau*, **37**, No. 5 (May, 1950).

RATIONAL DESIGN CRITERIA FOR SEWAGE ABSORPTION FIELDS *

By John E. Kiker, Jr.

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Introduction

It has been estimated that 17,000,000 persons in this country are served by residential septic tank—soil absorption systems (1). The majority of preferred sites for residential building are outside the limits of municipal sewer lines (2). Business establishments, camps, hotels, schools, and institutions that do not have access to public sewers must also provide their own facilities for the disposal of sewage. Such disposal may be in sewage absorption fields unless the quantity of sewage is too large or the soil unsuitable. The disposal area must be large enough to prevent public health nuisances from overflowing sewage that has not been properly treated. "On the other hand, installations of facilities in excess of those needed represent merely a waste of money. The ideal is to provide facilities that will just meet the needs under the conditions to be encountered. This is a basic engineering principle. In order to approach the ideal, it is necessary that the disposal system be designed scientifically" (3).

Percolation Tests

Most engineers agree that the leaching area required in sewage absorption fields can best be determined by percolation tests (4) (5) (6). As indicated in a recent Public Health Service publication (1), the percolation test was first proposed by Ryon in an unofficial publication of the New York State Department of Health. The soil tests described in "Bulletin No. 1" of that Department (7) were based on Ryon's work, which included studies of disposal systems that had failed or were about to fail after having operated successfully for a period of about 20 years. This work, insofar as it applied to sewage absorption fields, led to the development of standards which may be summarized as follows:

Time for Water to Fall 1 In. (min.)	Allowable Sewage Loading per Sq. Ft. of Trench (g.p.d.)
1	4.0
2	3.2
5	2.4
10	1.7
30	0.8
60	0.6

These data will be recognized by most engineers who have studied subsurface sewage disposal systems, as the criteria represented have appeared either in table or chart form in several texts and have become accepted as standard in many sections of this country. As indicated in the U. S. P. H. S. studies, however, the percolation test has often been adopted with unexplained changes (1). Similar unexplained changes have occasionally been made in the tabulated sewage loading rates.

Percolation Coefficient

A graph based on the reciprocal of the New York percolation rates gives a straight line for rates from 1 in. per min. down to 1 in. in 30 min. The graph deviates from a straight line only for the lower percolation rates (see Figure 1). The effect of this

* Presented at Twenty-second Annual Meeting, New York Sewage and Industrial Wastes Association; New York, N. Y.; Jan. 20-21, 1950.

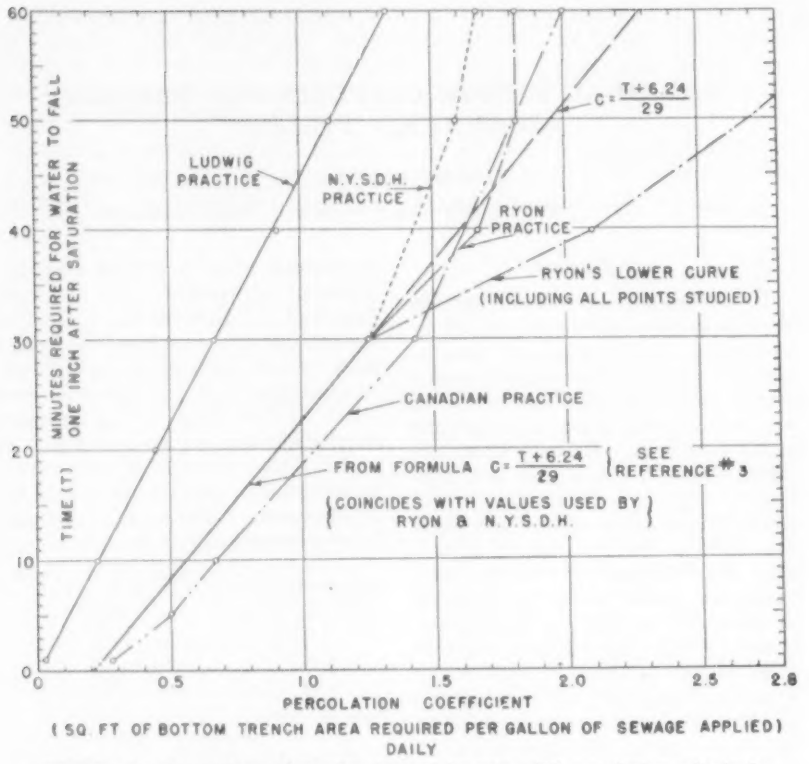

FIGURE 1.—Comparison of results obtained by using different design criteria for computing loading rates.

deviation is to allow in tight soil greater loadings than would be indicated if a straight line were maintained throughout the percolation range. This is believed to account, in part, at least, for failures that have been observed in tight soils. Although it might be expected that transpiration and surface evaporation at sewage absorption fields should permit relatively higher loadings in tight soil than indicated by the results of percolation tests, the hypothesis that such higher loadings could be justified has not been borne out in practice. For this reason, it was decided to suggest a standard that would more nearly coincide with field observations of actual installations.

This was accomplished by merely projecting the straight line beyond the 30-min. period, as illustrated in Figure 1. The reciprocal of the allowable sewage loading (g.p.d. per sq. ft.) was designated as the "percolation coefficient"; hence, this coefficient, which is readily obtained from the graph, represents the number of square feet of bottom trench area required for each gallon of settled sewage applied daily to an absorption field. A simple empirical formula for computing the percolation coefficient was first announced and published in 1948 (9).

The formula is simply

$$C = \frac{(t + 6.24)}{29}$$

in which C is the percolation coefficient

and t is the standard percolation time in minutes per inch. (One reason for having a percolation coefficient which increases as the percolation rate decreases was the usual familiarity of sanitary engineers with the uniformity coefficient of sand, where the coefficient increases with decreasing uniformity.)

It is somewhat interesting to recall the evolution of a manuscript for a bulletin (3) in which the formula was subsequently explained. One of the first questions raised was concerned with the justification for projecting the straight line beyond the 30-min. period. After considerable discussion, the explanations were acceptable and the straight line formula was adopted, but a later publication by Federick (8) giving more of the background of Ryon's original work was noted with much interest. Federick reproduced Ryon's curves showing the permissible loadings on subsurface irrigation systems for various percolation rates. He showed both the lines used in computing permissible loadings, as well as lines which included all points studied by Ryon. These data have been converted to the units used in determining the percolation coefficient and are shown in Figure 1. It is interesting to note that the projected straight line beyond the 30-min. point represents an approximate average of the other three lines. It is believed that ample justification for suggesting the straight line relationship is demonstrated by these data. On the other hand, the projection was based on experience and observations in the field, without regard to theoretical considerations.

In using the data, it is especially important that the percolation test be continued until the percolation rate becomes constant. This takes time and requires patience, especially in tight soil where an hour or more may be required at a given test hole. There is too much of a tendency to fill the hole once and to consider only the time during which the water level drops the first inch or two. This method has been found to indicate percolation rates from 2 to 10 times the rates obtained after saturation. It is to be noted that Ryon's data were based on tests in saturated soil. The tests simply cannot be speeded up, and there is no known method of accurately determining the minimum percolation rate from the readings taken during the first few minutes of any test.

Other Developments

If anyone considers it unreasonable to have to spend an hour or so at some test holes, he should read an excellent article by H. F. and G. W. Ludwig (10), who apparently have given a great deal of thought and study to the subject of determining capacities of soils for leaching sewage effluents. Instead of suggesting tests of 1 hr., however, these engineers recommend "a total period of testing of *not less than 6 hr.*" (italics added). In an example of a problem based on data obtained from an actual field test, they show that 10 hr. were required at a single test hole. They brought out some excellent points and stress the value of obtaining accurate fundamental data before proceeding with the design of a subsurface sewage disposal system.

The article has been especially intriguing to several persons in the Civil Engineering Department of the University of Florida, including two graduate students who have made a critical study of the so-called "Kiker" and "Ludwig" methods of determining soil capacities. Numerous percolation tests have been made both on the University campus and in residential areas at or near Gainesville, Fla. The conclusions, however, have not substantiated the need for testing periods of 6 hr. or more. Tests to date have indicated that the minimum percolation rate (after saturation) can be obtained with only one or two fillings of

most test holes. Reproductions of markings on the measuring sticks used during a series of tests in a typical test hole are illustrated in Figure 2. It is to be noted that the minimum results obtained during the fourth filling were substantially the same as those obtained when the hole was filled the first time. The results also indicate that 30 min. were adequate to determine the percolation rate, and that the last three tests normally would have represented 1½ hr. of wasted time.

Another interesting feature of the Ludwig article was the method suggested for determining "the amount of sewage effluent which may be leached away"; in other words, the required leaching area. The method consists of determining the maximum rate at which a stratum will "continuously" leach away clean water, dividing that rate by 20, and using the value so obtained as an estimate of the amount of sewage effluent that will leach away in the stratum.

The allowable sewage loadings computed by this method are given in Table I, Col. 5. The results of estimates by three older methods are also given in this table. It is to be noted that in loose soil the Ludwig method requires less than one-tenth the absorption area indicated by the older

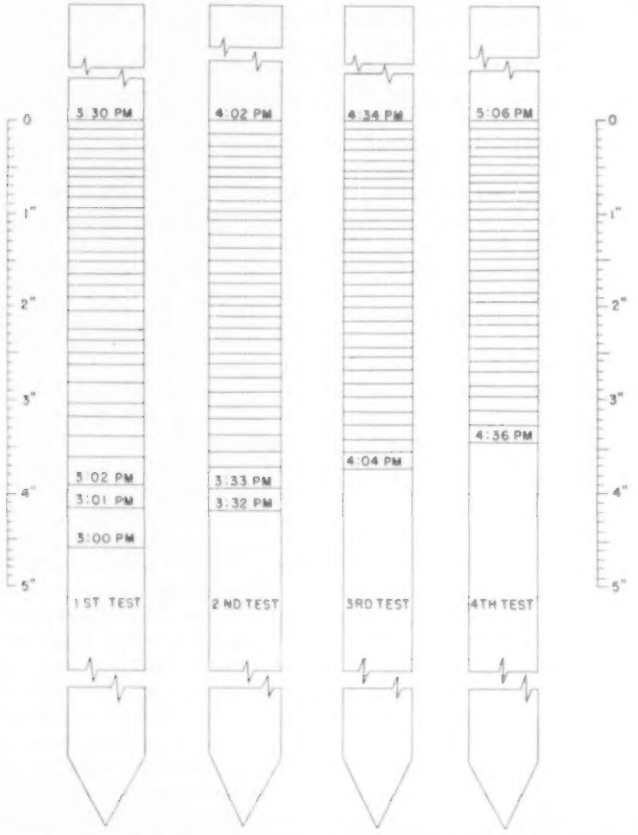

FIGURE 2.—Typical results of repeating percolation tests in the same hole.

TABLE I.—Relation Between Percolation Test and Allowable Loadings

Time for Water to Fall 1 Inch (min.) (1)	Allowable Sewage Loading per Sq. Ft. of Trench (g.p.d.)			
	N. Y. State (2)	$G = 29/(t + 6.25)$ (3)	Canada (4)	Ludwig (5)
1	4.0	4.0	3.5	45
5	2.4	2.6	2.0	9
10	1.7	1.8	1.5	4.5
20	1.1	1.1	—	2.25
30	0.8	0.8	0.7	1.5
40	0.7	0.6	—	1.1
50	0.63	0.5	—	0.9
60	0.6	0.44	0.5	0.75

methods, which have stood the test of time. In tighter soils, the results are more comparable, but there is still a considerable divergence. Recent tests indicate that soils at the University of Florida will continuously absorb 40 times as much water as settled sewage (12). By modifying the Ludwig method to the extent of using a 1:40 sewage-water ratio, the results thereby indicated will compare very closely with those obtained by the formula herein advocated.

It should be explained that Canadian practice (col. 4) apparently does not require saturation of the test hole before readings of percolation rates are taken. According to Berry (5), the test is made simply by excavating a 1-ft. square hole to the depth of the tile trenches, adding water to a depth of about 6 in. and observing the time required for the water to seep away. Some judgment is necessary in making the test, however, to insure that the soil is not abnormally wet or dry, but is representative of average conditions. The New York State rules (Col. 2) require that the effect of a dry hole be eliminated by repeating the test and using the slower rate of percolation. In the method described herein, (Col. 3), the necessity of judgment is reduced to a minimum by requiring that measurements be continued until the percolation rate becomes constant.

The fact that the rate usually becomes constant in a reasonably short time is a phenomenon not readily accepted by persons inexperienced with the percolation test.* A question frequently raised is how can the rate possibly become constant when the head of water in the test hole is constantly diminishing? One explanation is that as the head diminishes, the total leaching area or "wetting front" per unit of head or depth increases, and that the one partly offsets the other. This concept has been considered more applicable in loose soil than in tight formations, because the head differentials between readings may be too small in tight soil to make any measurable difference. A better explanation may be that the true hydraulic head includes the pull of the suspended water below the surface, and that this pull continues to be exerted, even after the water has all passed through the bottom of the hole. As the water level approaches the bottom, this head becomes reasonably constant (if not, the test is repeated) and the change in the side-wall seepage area becomes relatively small as compared with the bottom area. It is believed that these are the conditions that make for an asymptotic approach to an equilibrium condition such as is actually observed. Other explanations may be found in texts on soil mechanics and soil physics, but it is believed that the actual confirmations repeatedly demonstrated in the field are perhaps more impor-

* In recent experimental work using a sensitive apparatus for percolation measurements, soils have been found where there were slight decreases in percolation, rates on each successive test. This is to be expected where "after-precipitation" occurs in water used for the test. The additional absorption areas indicated by the sensitive tests, however, were within 5 per cent of the values indicated by conventional tests, and this is within the accuracy expected of field methods.

tant than any theories or reasons that may be given for them.

Loose Soils

In the case of very loose soil, it is sometimes advisable to add water continuously in order to obtain accurate measurements of absorption capacities. In some soils around Gainesville, shallow 1-ft. square test holes will receive clean water continuously at rates in the neighborhood of 2 g.p.m., representing percolation rates better than 3 in. per min. Such tests have been continued hour after hour with no signs of diminishing capacities. In such soils, however, it is not necessary to determine the minimum percolation rates. Most of the existing standards do not make allowance for rates in excess of 1 in. per min. In most areas, the failure to make such an allowance is not significant, because rates in excess of 1 in. per min. are seldom encountered. On the other hand, in areas where the soil is extremely pervious, the standards might be profitably revised to recognize the higher percolation rates. It now is suggested that the allowable sewage loading, in soil where a percolation rate greater than 2 in. per min. is obtained, be increased to 5.0 g.p.d. per sq. ft., which is equivalent to a percolation coefficient of 0.2.

Recent observations of absorption fields in extremely porous soils have led to another reversal of a previous opinion. In the past, it has been maintained that at least two percolation tests should be made at the site proposed for every sewage absorption field (3). It has been demonstrated, however, that in areas where there is an unusual uniformity of porous soil the percolation test may not be necessary in all cases.

Summary and Conclusions

The required leaching area in a properly constructed sewage absorption field can be determined with reasonable accuracy from the empirical formula

$$C = \frac{(t + 6.24)}{29}$$

in which C is the percolation coefficient or the number of square feet of bottom trench area required for each gallon of sewage applied daily, and t is the maximum time required for water to fall 1 in. during percolation tests in saturated soil. The test should be made in a hole that has been dug approximately 1 ft. square to the depth of the tile trenches.

Experience has proven that absorption fields designed on the basis of these criteria may have a life expectancy of about 20 yr., provided the fields are carefully constructed in accordance with standards recommended by the U. S. Public Health Service (11) and most State Health Departments.

It is realized that the percolation tests may have some theoretical weaknesses. There is also a practical limit to the accuracy of the measurements under field conditions. Results of tests made in pervious soil underlain by an impervious stratum do not mean much. High ground-water tables may also invalidate the results. The test cannot be made properly in frozen ground. Soils which swell when water is added may require many hours before equilibrium conditions can be obtained. Usefulness of the test under most conditions has been proven by time, however, and when the results are interpreted with discretion the test offers the best available yardstick for determining soil capacities. The character of the underlying soil for a depth of several feet below the bottom of a test hole should be considered when interpreting the results. Prolonged tests, as recommended by Ludwig (10), are of value when unusual conditions are encountered.

The subject of this paper precludes any discussion of leaching pits as a means of sewage disposal. In some cases, however (for example, where

impervious soils are underlaid with porous sand or fine gravel), leaching pits may offer the cheapest and the best solution to disposal problems. They should have a leaching area equal to about 70 to 75 per cent of that required in an absorption field, but they should not be used where there is danger of contributing to the pollution of ground water supplies.

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DISCUSSION

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The respect Professor Kiker shows to the percolation test is both impressive and pleasing. As he says, the percolation test is far from perfect, either theoretically or practically. Nevertheless, experience with systems designed on the basis of the test has proven its worth.

The formula for the percolation coefficient developed by Professor Kiker should be a valuable tool when, in the future, percolation tests are used in designing sewage absorption fields. Apparently, the formula will allow a more flexible adjustment of absorption areas required and will result in more accurate design, particularly when additional information is produced on the relationship between percolation rates and allowable loading rates on a wider variety of soils.

The trench area requirements are usually given, in the various design specifications, on the basis of percolation rates tabulated in round numbers. The measured percolation rate for any system must either be rounded off to the nearest rate given in the tables, resulting in under-designed or over-designed systems; or the required trench areas must be interpolated from the tables, in many cases resulting in an approximation. The basis of the formula seems to be close enough to the original Ryon data (which, according to the author, "has been proven

TABLE I.—Relation Between Percolation Test and Allowable Loadings

Percolation Rate			Allowable Sewage Loading Rate							
			N. Y. State		Kiker		Canada		Ludwig	
(min./in.)	(in./hr.)	(g.p.d./sq. ft.)	(g.p.d./sq. ft.)	(% of Perc. Rate)	(g.p.d./sq. ft.)	(% of Perc. Rate)	(g.p.d./sq. ft.)	(% of Perc. Rate)	(g.p.d./sq. ft.)	(% of Perc. Rate)
1	60	897.6	4.0	0.45	4.0	0.45	3.5	0.39	45.00	5.0
5	12	179.5	2.4	1.34	2.6	1.50	2.0	1.11	9.00	5.0
10	6	89.8	1.7	1.79	1.8	2.00	1.5	1.67	4.50	5.0
20	3	44.9	1.1	2.45	1.1	2.45	—	—	2.25	5.0
30	2	29.9	0.8	2.68	0.8	2.68	0.7	2.34	1.50	5.0
40	1.5	22.4	0.7	3.12	0.6	2.68	—	—	1.10	5.0
50	1.2	17.9	0.63	3.51	0.5	2.79	—	—	0.9	5.0
60	1	14.9	0.60	4.01	0.44	2.94	0.5	3.42	0.75	5.0

by time") so that there should be no doubt as to its usefulness to our present knowledge.

It is interesting to inspect a little more closely the "Relation Between Percolation Test and Allowable Loadings" presented in Professor Kiker's Table I. The percolation rates have been recalculated from units of minutes per inch of fall to gallons per square foot per day, in order that the percolation rates and the allowable sewage loading rates may be compared directly. This comparison is shown in Table I. There appears to be a remarkable reduction in the allowable sewage loading rates compared to the measured percolation rates. In the New York State table, the allowable sewage loading rate varies from 0.45 to 4.01 per cent of the measured percolation rate; in the Kiker table, from 0.45 to 2.94 per cent; and in the Canadian table, from 0.39 to 3.42 per cent. The Ludwig table, of course, is based on the allowable loading rate being 5.0 per cent of the percolation rate. As the Ryon study was based on systems that had failed after 20 years of operation, and as most of the other tables appear to be based on the general background of the Ryon data, it might be said that the absorption rate of a soil after being dosed with septic tank effluent for 20 years is only from 0.39 to 5.0 per cent of the original absorption rate as measured by a percolation test.

A complicated set of variables is involved in this large correction factor. Possibly the most important factors are the estimate of the original percolation rate, the clogging effect of sewage effluent on the soil absorption rate, and the estimate of actual loading rates of operating systems. Only the first two factors are considered here, as it has not yet been possible to give any attention to the third factor.

Improvement of the percolation test seems to be a logical method by which the discrepancy between measured percolation rates and allowable loading rates eventually can be accounted for. Despite the usefulness of the percolation test and its modifications to date, there is considerable room for improvement in the method of making the test and the method of analyzing data from a test. These remarks, therefore, will have to be classed as opinion based on past experience and observation, rather than on any specific data available to date. The problem is being studied, however, under a cooperative research project between the Public Health Service and the Housing and Home Finance Agency at the Environmental Health Center in Cincinnati. A report on the prelimi-

nary work is in preparation and should be available soon.

In many cases the percolation test is not giving a measure of the minimum or equilibrium absorption rate of the particular soil under test. It is interesting to learn of the "improved method" described by Professor Kiker as being introduced about 1937, and that comparison to the original method indicated it was just as reliable and more conservative. It is well to repeat and emphasize here Professor Kiker's statement that "it is especially important . . . that the percolation test be continued until the percolation rate becomes constant." The "improved method" is insurance towards this end.

Also, in this connection, it is believed that Professor Kiker is very conservative in stating that in tight soils an hour or more may be required at a given test hole to obtain an equilibrium rate. A continuous decrease has been observed in percolation rate during percolation tests for 6 to 8 hr., even after overnight soaking periods. This is particularly true in soils having a high clay content. Such soils may have a blocky type of structure that allows for a rather high initial rate, but swelling within the structural units can cause a large decrease in percolation rates extending over a long time. Consequently, it is believed that percolation tests continued over extended periods would be an improvement in many cases.

The Ludwigs (3) recommend periods not less than 6 hr. The writer would be inclined to go even further and favor a pre-saturation and soaking period before the critical test is performed. In support of this opinion, it is common practice in agricultural permeability studies to make a "dry run" and a "wet run" in order to secure critical permeability or percolation data (5). The "dry run" is more or less a typical percolation test. The "wet run" is a repeat test made after the soil has had sufficient time to soak and swell—often an overnight process.

Another possible improvement of the percolation test would be to require more replication of tests in areas under consideration, particularly in soils having the slower percolation rates. Experience indicates that it is not unusual to find percolation rates varying from 5 or 6 in. per hr. to fractions of an inch per hour in test holes within 20 to 30 ft. of each other. In some cases, this may indicate a significant difference in permeability; in some cases, it may be caused by unnatural conditions in the test holes (such as when hidden obstructions not characteristic of the soil as a whole underlie the pit, thus causing reduced rates; or when the pit cuts into or near extraneous but not readily detectible channels, thus causing excessive percolation rates). Replication of test would tend to average out any unusual rates.

In areas of homogenous soil, particularly in the faster percolation ranges characteristic of sandy soils, precautions employed to insure minimum rates are probably not necessary. The soils of large areas in Florida are typical of this type. Many of these soils contain only small amounts of clay and colloid; consequently, there is very little swelling and the accompanying decrease in percolation rates. No need is seen for lengthened percolation tests of these soils.

The second major variable, one that may help account for the apparent discrepancy between measured percolation rates and allowable loading rates, is the clogging effect of sewage on soils. This clogging effect can be logically considered in three parts; namely, physical clogging, chemical clogging, and biological clogging.

The strictly physical clogging effect is obvious. Solid particles in the sewage can stop off or fill soil pores, through which moisture customarily

moves. The magnitude of such clogging depends on the amount of solids in the sewage and the amount and size of pores in the soil. The larger the amount of solids and the smaller the pores, the greater the amount of clogging that may be expected. This type of clogging is analogous to sealing in surface soils when they are irrigated or flooded with silty waters.

The chemical type of clogging is a little more complex. It may be caused by a dispersal of the soil structure by chemicals in the sewage, resulting in decreased pore space and in smaller pore sizes; or it may affect the base exchange complex of the soil in such a way as to change its absorption characteristics. Sealing or clogging of this type is typical in some western soils when waters high in sodium are used for irrigation (2)(3). It is quite possible that conditions may be favorable for this type of clogging in sewage absorption systems.

The third, or biological, type of clogging is also a typical type, occurring in continuously submerged soils; for instance, in water spreading basins (1). The biological type may actually be a combination of the other two types. The biologic life and by-products (slimes and mucus-like materials) may produce a physical clogging. Certain of the by-products may also have a chemical dispersal effect on the soil structure. In some cases, dispersal effects on the soil structure also may result from a microbial attack on the substances that bind soil particles together.

If and when the most important causes of soil clogging under absorption field conditions are determined, it may be possible to understand the apparent discrepancy between measured rates and allowable loading rate a little better. It may then be possible to apply corrective measures to the soil clogging problems and incorporate them into design principles.

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Industrial Wastes

REVIEW OF LITERATURE ON TOXIC MATERIALS AFFECTING SEWAGE TREATMENT PROCESSES, STREAMS, AND B.O.D. DETERMINATIONS

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Over a period of years, the Research Committee has presented an annual review of the literature pertaining to new and improved methods of sewage and industrial waste treatment, the effect of wastes on stream conditions, development of analytical methods, and various changes and improvements in the art of waste handling and disposal. It has become increasingly evident that with the expansion of industrial enterprises the increase in the extent of pollution is only one factor in the treatment of waste. The great variety of toxic, retarding, and inhibiting substances present in a number of wastes discharged into municipal sewers or directly into receiving waters affect biological treatment devices, the self-purification of streams, fish food and fish life, and analytical methods. The literature pertaining to the effect of toxic substances is widely scattered. The effect of toxic substances on the B.O.D. determinations is not clearly understood. There is no standardized method of gaging properly the effect of toxic substances on plankton or fish.

For these various reasons, the Research Committee has established a subcommittee on toxicity, which is divided into three main sections with the following assignments:

Section I.	Review of literature.
Section II.	Study the effect of toxic materials on the B.O.D. test.
Section III.	Develop and standardize bio-assay procedures and methods for the evaluation of the toxicity of wastes to fish, fish food, and the application to waste disposal problems.

Section I.

Inasmuch as the literature on toxicity is primarily found in publications devoted to biology, zoology, fish culture, and wild life, and is in some phases very extensive, the review of literature must be critical and rather comprehensive. Without making the literature survey a historical review, the papers, bulletins, pamphlets, and books published during the last 25 years are primarily considered, but older material, which may be of importance, has been searched. An attempt has been made to present a running story rather than a series of abstracts, presenting the salient points with some illustrative data of specific interest.

For purposes of convenience, and because of the extent of the literature

involved, the review has been divided into two general parts. The first part comprises the effect of toxic materials on sewage treatment processes, including the effect of inorganic and organic substances on anaerobic processes, aerobic processes, the effect on self-purification of streams on the microflora and fauna, and the effect of toxic materials on the B.O.D. test.

The second part of the review, to be published later, deals with the effect of toxic materials on fish. The literature on the toxicity of industrial wastes and their components to fish is very extensive and probably will be published in five parts over a more or less extended period of time. The subject has been tentatively divided into the following classifications:

1. Acids, alkalies, and inorganic gases.
2. Inorganic salts and miscellaneous inorganic substances.
3. Organic compounds.
4. Complex industrial wastes.
5. Bio-assay methods.

It is the intention to bring the literature survey up to date every 2 or 3 years. Each section of the review will contain a brief summary, if possible, in tabular form.

Section II.

The study on the effect of toxic materials on the B.O.D. test is under way and some experimental data have been gathered. From time to time, parts of these studies will be published, and eventually the results of these studies will be used in an effort to standardize procedures.

Section III.

The program dealing with the development of procedures and bio-assay methods for the study of toxicity is ambitious and probably will require several years of study and experimentation. The chairman of this subsection, P. Douderoff, has been able to assemble an outstanding group of people interested and qualified to do this work.

Value of Program

The value of the entire program is three-fold:

1. The critical review of the literature on toxicity should bring together in one place material frequently difficult to obtain. Also, it should be a guide for detailed information, and give the reader a comprehensive view of the entire problem.

2. The work on toxicity limits and effect of toxic materials on the B.O.D. test should make this determination more valuable, establish the limitations of the test, and indicate what may be expected when industrial wastes are present in sewage. Furthermore, it should aid in answering a number of questions raised concerning the value, interpretation, accuracy, and importance of B.O.D. determinations of a number of industrial wastes.

3. The program launched on procedures and bio-assay methods is undoubtedly of great importance. If standard procedures and methods can be developed to determine with a degree of accuracy the effect of toxic materials on fish and fish food, a much needed tool would be available. It is not intended to wait until a fool-proof, complete set of methods is developed, but rather to publish in an orderly manner procedures, tentative methods, and, finally, standard methods, which may be modified or improved when additional information becomes available.

I. EFFECT OF ORGANIC AND INORGANIC WASTES ON ANAEROBIC PROCESSES

Organic Wastes

Rudolfs (17) studied the effect of sulfur black dye on the digestion of fresh sewage solids. The results of these studies indicated that digestion was inhibited when the dye waste was allowed to stand in direct contact with the sludge. This effect was less marked when the wastes were continually removed with the supernatant liquor.

In a report of studies on the effect of certain toxic wastes on high and low temperature digestion, Rudolfs (19)(20) found that, in the mesophilic range, gasoline in amounts up to 0.2 per cent by volume of the fresh solids added had little effect on digestion. Amounts greater than 0.2 per cent definitely retarded digestion, whereas with 1.0 per cent the time of digestion was doubled. Eventually, however, the same amount of gas was produced by the gasoline contaminated sludge as by the control, even up to 1.25 per cent gasoline. Seeding with previously digested gasoline sludge did not accelerate digestion. In the thermophilic range the toxicity of gasoline was very evident. The time required to produce 90 per cent of the available gas was double that of the control. The effect of crankcase oil in amounts from 1.0 to 2.5 per cent by volume of the fresh sludge indicated that there was no detrimental effect on gas production in the mesophilic range. There was, however, an increase in the total quantity of gas produced and a decided decrease in the volatile matter destruction of the fresh solids, which indicated that at least part of the gas produced was the result of decomposition of the oil. The addition of oil also adversely affected the drainability and drying quality of the digested sludge, even after long periods of digestion. In the thermophilic range, the effect of crankcase oil on gas production and volatile matter reduction of the fresh solids was much the same as that produced in the lower temperature range. Additions of tannery waste composite up to 14 per cent by volume produced as much, or more gas than the control. Blood wastes produced violent foaming, low volume of gas per gram of volatile matter, and an odorous sludge. Wool scouring wastes up to 10 per cent by volume had only a very slight retarding effect on gas production; 20 per cent of the waste increased digestion time by one-fourth. Gas production was decreased 35 per cent by 10 per cent of rug dye waste. Larger quantities of the waste further retarded digestion. By the use of acclimatized sludge as seed, the quantity of these organic wastes which could be digested was increased from 15 to 20 per cent to 20 to 40 per cent on the basis of volatile matter in the fresh solids. In the thermophilic range these wastes had little effect on digestion in amounts up to 10 per cent, and only a slight retardation in amounts up to 20 per cent. Acclimatizing the sludge was accomplished more easily in the higher temperature range and the quantity of organic waste which could be digested equaled that of digestion in the lower range. Gas production also was as great; digestion time was considerably reduced.

In studies on the effect of solvents used in industry on anaerobic digestion processes, Rudolfs (21) found that additions of small quantities of methyl, ethyl, butyl, and isoamyl alcohol, in amounts up to 0.1 per cent by volume, stimulated gas production but slightly retarded volatile matter destruction. With larger quantities, up to 0.5 per cent, both gas production and volatile matter destruction were decreased. Ethyl ether up to 0.5 per

cent had no effect on volatile matter reduction, but stimulated gas production. Acetone in amounts up to 0.5 per cent had no appreciable effect on gas production, but increased volatile matter reduction. Toluene and carbon tetrachloride in amounts as high as 0.05 per cent aided gas production without materially affecting destruction of volatile matter. Larger quantities definitely inhibited digestion. Benzene and xylene in quantities of 0.1 per cent and greater seriously retarded digestion. They appear to be toxic to both gas producing and liquifying organisms. Ethylene dichloride is very toxic to anaerobic digestion, even in minute quantities. Both gas production and volatile matter destruction were greatly inhibited by amounts as low as 0.001 per cent, and practically stopped by 0.05 per cent. In most of the cases cited, the allowable quantities of solvent are greater than would normally be found in industrial wastes treated in conjunction with sewage. Ethylene dichloride is an exception, as the solubility of this hydrocarbon is such that toxic conditions might easily occur.

Ridenour *et al.* (12) studied the effect of polysulfide treated cyanide wastes from carburizing and plating processes on digestion of sewage sludge. The results showed that in batch process addition of carburizing waste up to 7,500 p.p.m. did not affect the rate of gas production. Increased amounts beyond this concentration depressed both the rate and quantity of gas produced, although at no concentration up to 15,000 p.p.m. was there any definite critical toxicity shown. In the case of continuous daily additions, the limit of tolerance was 1,200 p.p.m. With respect to the quality of gas produced, there was no appreciable effect on the carbon dioxide-total gas ratio. There was, however, an increase in hydrogen sulfide somewhat in proportion to the amount of waste added. Zinc-plating and copper-plating solutions had a tolerance up to 2,500 p.p.m. in batch process. Beyond this concentration both the rate and the quantity of gas was reduced, but with no critical toxic limit up to 6,000 p.p.m. In continuous daily additions, a charge of more than 600 p.p.m. in the case of zinc and 300 p.p.m. in the case of copper were necessary before gas production was affected. The tolerance of sludge for sodium cyanide, one of the residual constituents of carburizing wastes, was very low (3 p.p.m.) when first introduced. However, a tolerance for the cyanide is built up after a few days until quite a large daily increment can be absorbed. Daily additions of sodium thiocyanate up to 250 p.p.m. indicated no effect on digestion. Further additions reduced the rate and quantity of gas production until, in concentrations of 1,000 p.p.m., the effect was pronounced. The calcium polysulfide constituent of these wastes gave evidence of adverse effect at 100 to 200 p.p.m.; at 500 p.p.m. digestion was completely retarded. Except under very abnormal conditions, these wastes could be admitted to the sewerage system of a normal community without danger to the anaerobic processes at the sewage treatment plant. The most significant influence of these wastes on the quality of the digester gas was an increase in the proportion of hydrogen sulfide.

Ridenour (11) studied the effect of alkali chlorinated cyanide wastes on anaerobic digestion processes and concluded that because this method of treatment destroys the cyanide and could only be due to the influence of thiocyanate groups, any indication of retarding effect on gas production the toxic metals present.

Scriver and Badger (26) described experience with spent gas liquor on cold digestion. They found that by controlling the flow of gas liquor no adverse effects would be produced on

the digestion of sludge in unheated tanks.

Wilkinson (29) found that under laboratory conditions sewage containing 60 p.p.m. of trinitro-toluene digested almost as readily as sludge from sewage to which no addition had been made.

Rudolfs, Manganelli, and Gellman (23) showed that some synthetic detergents had no material effect on volatile matter destruction, grease reduction, or gas production when present in concentrations up to 100 p.p.m. However, due to the decrease in sludge quantity, as well as the grease retained by the sewage solids during sedimentation, a reduction in quantities of gas produced is manifested.

Degens *et al.* (5) demonstrated that no interference with methane fermentation was apparent when the raw sludge contained less than 500 p.p.m. active detergent. They found that the yield of methane per gram of carbon is the same for synthetic detergent and fatty acid soap. The amount of methane produced was less with synthetic detergents, because a smaller amount of the detergent goes into the raw sludge than in the case of the fatty acid soap.

Inorganic Wastes

Setter (27) reported that gasification was not affected by the presence of less than 5 p.p.m. of ferric chloride, but was progressively retarded by increasing concentration of ferric chloride up to 20 p.p.m. Part of this retardation was attributed to the acidity created by the hydrolysis of ferric chloride, which was overcome by the addition of lime. The numbers of bacteria in fresh solids treated with 10 p.p.m. of $FeCl_3$ were greatly reduced. The rate and quantity of oxygen absorbed by fresh solids was independent of the quantity of iron compounds present. Rudolfs and Setter (24) reported further on the effect of treatment of fresh solids, ripe sludge, and mixtures of both with ferric chloride on the digestion of the materials. Treating fresh solids increased the rate of digestion, but less gas was produced. There was no effect on digestion when ripe sludge or mixtures were previously treated with $FeCl_3$. Rudolfs, Baumgartner, and Setter (22) found that alum retarded digestion and produced less gas. Rudolfs and Zeller (25) reported that the addition of 1,000 p.p.m. of various compounds of sulfate reduced gas production. Zinc and copper sulfates and sulfuric acid had the most pronounced effect; sodium, calcium, magnesium, iron, and aluminum sulfates had less effect, and ammonium sulfate had the least effect.

The addition of sodium chloride up to 50,000 p.p.m. concentration had little effect on the rate of decomposition of sewage sludge according to Rudolfs (18). With larger quantities, the destruction of volatile matter and total gas production decreased markedly. Above 50,000 p.p.m. concentration the addition of salt resulted in negligible methane production. Buswell, Pagano, and Sollo (2) reported that sodium sulfate in concentrations of 4,000 p.p.m. or more makes methane fermentation of glucose at 55° C. impossible. Acetic acid can be readily fermented in the presence of as much as 10,000 p.p.m. of sodium chloride or sodium sulfate at 37° C.

Fischer, Rudolfs, and Zeller (6) found that sodium nitrate hastened the decomposition and caused more complete digestion, but the effect on gas production was not given. Straub (28) concluded that sodium nitrate reduced the amount of gas produced. Less methane and more nitrogen gas was obtained by the addition of sodium nitrate, but the breakdown of volatile solids was more complete.

Rudolfs (17) reported that gas production was slightly affected by copper sulfate concentration up to 0.025 per cent of the total mixture. Rudgal

(14)(15) noted a lower gas production with 150 to 250 p.p.m. of copper in the batch digestion of fresh solids; 50 p.p.m. of copper added to the daily charge of fresh solids resulted in decreased gas production after about two weeks. The same author (16) later reported on the basis of experiences at Kenosha, Wis., that 2,500 p.p.m. copper in the raw sludge on the wet basis, interfered with digestion. Gas production dropped from 12 to 13 cu. ft. per lb. of volatile solids added to 10 cu. ft. with 0.4 per cent of copper on the dry solids basis, and to 5.5 cu. ft. with 0.95 per cent copper on the same basis. In experimental work with thermophilic digestion, copper showed the same relative inhibiting effects. When the concentration of copper in the fresh solids decreased 0.25 to 0.35 per cent on a dry solids basis, the digestion tanks produced 12 cu. ft. of gas per lb. of volatile solids added and sludge digestion was not adversely affected (15).

Barnes and Braidech (1) obtained a 49.4 per cent retardation of gas production by the addition of 4,000 p.p.m. of cuprous copper to unseeded fresh solids; 1,000 p.p.m. gave 14.9 per cent reduction of gas production. Coburn (4) set the concentration of copper in sewage at 1.0 p.p.m. when sludge digestion is to be practiced; Laboon (8) gave the same limiting concentration of copper in sewage. Riehl (13) reported that, in actual plants, normal digestion took place when the sewage contained 0.2 p.p.m. of copper and 5 p.p.m. of zinc, whereas 2.4 p.p.m. of copper and 20 p.p.m. of zinc in sewage stopped sludge digestion. Ridenour, Backus, and Sherron (12) noted that with daily additions the tolerance limit of copper-plating solution was 200 p.p.m., whereas with batch digestion the limit was 2,000 p.p.m. After alkali chlorine treatment the concentration of copper-plating solution that can be handled without affecting digestion is greatly increased according to Ridenour (11). Wise (30) reported that sewage containing 0.5 p.p.m. of copper produced sludge containing over 100 p.p.m. A decrease in the efficiency of digestion can be expected when the constant amount of copper in the sewage exceeds 1 p.p.m.

Barnes and Braidech (1) found that 2,000 p.p.m. trivalent chromic chromium retarded digestion 11.6 per cent, 5,000 p.p.m. trivalent chromate chromium retarded the digestion 41 per cent, and 10,000 p.p.m. of hexavalent chromium retarded the digestion by 68.4 per cent. Coburn (4) states that trivalent chromium will precipitate in an alkaline solution, such as sewage, and will be removed as sludge to digestion tanks, where digestion will be retarded or stopped. Chromium in hexavalent form is not precipitated and, therefore, the amount showing an effect on sludge digestion will be very much lower. The concentration limit of chromium in sewage is set at 5 p.p.m. without affecting the sludge digestion process, which is the same value as given by Laboon (8). Wise (30) states that digestion efficiency is decreased when chromium in sewage exceeds 1 p.p.m. and when chromium in the sludge is 200 p.p.m.

Kneale and Lucas (7) found that 1,000 p.p.m. of zinc added as $ZnSO_4$ produced no significant reduction in gas production. Greater amounts proved significantly inhibitory. Riehl (13) reported that when sewage contained 5 p.p.m. of zinc and 0.2 p.p.m. of copper, digestion proceeded normally; but with 20 p.p.m. of zinc and 2.4 p.p.m. of copper in sewage, sludge digestion stopped. Riddick (10) reported that a waste containing mercury and zinc inhibited sludge digestion. Allowable concentration of zinc-plating solution in batch sludge digestion was set at 2,500 p.p.m., and for daily additions at 600 p.p.m. by Ridenour, Backus, and Sherron (12).

Barnes and Braidech (1) obtained

100 per cent retardation of digestion with 100 p.p.m. of cyanide ($CN^=$). Coburn (4) and Laboon (8) set the limit of cyanide content in sewage at 2 p.p.m. for satisfactory sludge digestion. Lockett and Griffiths (9) found that 4 p.p.m. of cyanide (HCN) prevented the decomposition of sewage over a 4-day period. The tolerance of sludge for sodium cyanide was 3 p.p.m. when first introduced, but the tolerance was built up after a few days until a large daily increment could be absorbed according to Ridenour, Backus, and Sherron (12). Daily additions of 250 p.p.m. of sodium thiocyanate indicated no effect on digestion. Further additions reduced the rate and quantity of gas produced, until at 1,000 p.p.m. concentration the effect was pronounced. The calcium polysulfide constituent of these wastes gave adverse effect at 100 to 200 p.p.m.

Barnes and Braidech (1) obtained a 9.4 per cent reduction in digestion with 500 p.p.m. of nickel (Ni). Chapman and Wischmeyer (3) found that 500 p.p.m. of nickel added as nickel sulfate and nickel ammonium sulfate did not retard digestion. Higher concentrations proved toxic.

Rudolfs (19) obtained a material reduction of digestion with 4 p.p.m. of sodium arsenate.

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II. EFFECT OF INORGANIC AND ORGANIC WASTES ON AEROBIC PROCESSES

Many kinds of industrial waste have interferred with aerobic sewage treatment processes, although in most reports on waste treatment troubles the data are meager. Undoubtedly, the toxic effect of a waste will depend on the characteristics of the treatment plant and the conditions prevailing at the time the wastes are received. Therefore, no exact limiting concentrations of waste can be given.

Organic Wastes

Abnormally high concentrations of organic materials will, by themselves, be detrimental to aerobic treatment processes. Aerobic processes are limited, according to Buswell (10), first by their inability to treat liquids of high concentration, and secondly by their inability to handle coarse solids. Activated sludge may become overloaded, states Edwards (19), by absorbing more decomposible organic matter than there is oxygen available for its oxidation. A good sludge may deteriorate by the addition of an abnormally strong sewage and may be overpowered if overloading is long continued. When trickling filters are used with concentrated liquids, they become clogged; activated sludge tanks become septic (10). Dienert (16) claims that multiplication of zoogleal-forming bacteria is very slow when organic matter is too concentrated in the liquor, and that this organic matter is then transformed and degraded by proteolytic bacteria. When any considerable amount of carbohydrate and fermenting wastes are present in sewage, the diseases that may occur to aerobic treatment processes are activated sludge bulking and filter clogging (6). Carbohydrate and fermenting wastes are said to be the most detrimental to biological processes.

Lackey and Wattie (38) state that bulking of activated sludge can be produced experimentally by heavy doses of sugars. Ingols and Heukelekian (31)(32) found that bulking occurs when sludge fed with sugar is agitated with a limited amount of oxygen. With a relatively large amount of carbohydrate, such as glucose, and a limited amount of nitrogen, the zoogleal organisms could not completely utilize the carbohydrate, and left an excess to stimulate growth of *Sphaerotilus*. With an abundance of nitrogen and fairly large amounts

of glucose, the zoogleal organisms can compete with *Sphaerotilus* only for a short time, as in the presence of glucose the *Sphaerotilus* develops at a much higher rate than the zoogleal organisms. The optimum C/N ratio to retard bulking is approximately 8 to 1.

It is evident that organic wastes, as such, may affect aerobic sewage treatment processes, but not necessarily because they are toxic to organisms responsible for purification. The difficulties encountered, as evidenced by a large number of statements and results in the literature, are primarily the result of excessive loading. Although high loadings of organic wastes may be detrimental and inhibitory, they cannot be considered as toxicity factors in the sense of being poisonous. For this reason, many references referring to organic wastes, which may be detrimental when present in excess but do not exhibit specific toxicity, have been left out of this review.

Oil and Grease

A relatively small amount of oil, states Warrick (72), will very materially interfere with the efficiency of operation of activated sludge plants. The high surface tension of oily sewage, reports Hyde (30), reduces the efficiency of aeration. Moreover, the presence of mineral oil in considerable quantities may have a toxic effect on the biological organisms involved and may seriously interfere with their proper functioning. The efficiency of aeration is reduced by the presence of oil, according to Bolenius (8), as shown by a decrease in dissolved oxygen and nitrification even though the amount of applied air remains constant. Oil wastes originating from oil refineries, garages, service stations, and automobile plants, claims Oeming (48), do not appreciably add to the initial B.O.D. of sewage, but have a detrimental effect on sedimentation and oxidation by trickling filters or activated sludge process. It is well-known that oil refinery washings contain large quantities of mercaptans and other sulfur compounds, and they exert a detrimental influence on biological treatment. In a discussion, Rudolfs (26) stated that not only were unsightly conditions produced by small quantities of mineral oil, but that the oil also interferes with biological activities because of the formation of a film on sludge particles and coating of floc, stone, and sand. The toxic action is not exerted until a considerable concentration is reached, but interference in the work of aerobic organisms, by preventing the penetration of oxygen into the activated sludge floc or trickling filter film, is more serious. Several plants have reported similar difficulties. Marion, Ind. (7), received discharge of fuel oil, and Cleveland, Ohio, oil and grease. At the Chicago, Ill., North Side works (51), mineral oil reduced the efficiency of aeration, and at San Antonio, Tex., oil prevented the building up of activated sludge.

Tannery

There are two types of tanning process—vegetable tan and chrome tan (48). Wastes from the vegetable tan process contain more organic material and are, therefore, higher in oxygen demand. The major effect of these wastes on sewage treatment processes is an increase in the sludge volume. Vegetable tan liquor is highly colored and the appearance of the plant effluent would be impaired. The B.O.D. load on secondary units would be greatly increased.

Coburn (11) reported that tannery wastes caused a 155 per cent increase in suspended solids, and 115 per cent in oxygen consumed values, over normal at the Gloversville, N. Y., sewage treatment plant. Tannery wastes interfered with the activated sludge process at Milwaukee, Wis. (51).

Textile

Textile wastes (such as mercerizing, kier, and bleach) contain ingredients which produce large amounts of sludge when oxidized and neutralized, and, because they are strongly alkaline have a disinfecting action (22). The greatest damage done by textile wastes results from their irregular discharge and their rapid change in character (5). Bacteria are slow to adapt themselves to conditions which are constantly changing.

Dye Waste

Waste liquors resulting from the manufacture of dyestuffs do exercise a slight inhibitory action on the purification process by activated sludge (42). Sulfur and vat dye waste are very damaging to biological purification unless they are present in exceedingly small quantities (5).

Additions of dye waste frequently cause trouble in activated sludge plants because of toxic action on the organic growth. However, the so-called harmful effect of this liquor, according to Shibata (59), can be traced to its disturbing action on the pH range desirable in the activated sludge process and to the considerable color that remains unchanged at the end of treatment. Sewage containing this waste liquor is unsuitable for the activated sludge process if it has a pH of more than 8, but for pH 6 to 7 the color may be tolerably removed by a two-stage activated sludge process.

Sulfide dyes are applied to vegetable fibers in solution containing sodium sulfide and alkali. The waste liquor has a B.O.D. of 10,000 p.p.m. These wastes are objectionable because they may interfere with the process of purification, cause corrosion, and liberate hydrogen sulfide. It has been found that concentrations up to 3 per cent of waste can be treated with sewage by the activated sludge process (43).

Interference by dye wastes has been reported in the activated sludge plant at Waco, Tex. The dye wastes from a textile plant, according to Henderlite (25), not only colored the sewage plant effluent but also disrupted the activated sludge process at Gastonia, N. C., and caused serious trouble from sludge bulking. He added ferric chloride to raw sewage entering the aeration tanks and was able to produce a practically colorless effluent, with improvement in the sludge.

Hiura (27) studied the effect of silk Ponceau G, benzopurpurin B, Congo red, Japonal dark green B, benzo brown B, chrysophenin G, auramine O, crystal violet, rhodamine B, phosphine, and methylene blue B on biological purification, especially on the activated sludge process. Particularly in concentrations greater than 1 per cent, the basic dyes generally had a much more injurious effect on the activated sludge process than the acid dyes, as measured by nitrification and oxygen consumed tests. The most injurious action was exhibited by silk Ponceau G of the acid dyes and by crystal violet of the basic dyes. Practically no biological purification took place when waste water contained more than 1 per cent of crystal violet. Harmful effects increased with the increase in dye concentration. Some dyes, such as rhodamine B and methylene blue B, shift the reaction to the acid side, so that they not only inhibit the development of the bacteria or protozoa, but also prevent the formation of various hydroxides from inorganic salts.

Synthetic Detergents

Rudolfs, Manganelli, and Gellman (55) showed that in the presence of detergents there is decreased efficiency of settling tanks, with consequent increased load on trickling filters.

Seiver (58) also demonstrated the adverse effect of synthetic detergents on sedimentation.

Goldthorpe *et al.* (23)(24) pointed

out that the carrying forward of suspended solids to the trickling filters will increase the loading. This extra load, being in a very finely dispersed or solubilized state, may or may not be in a condition suitable for biological oxidation. Further work showed that the effect of synthetic detergents on percolating beds was one of slow, cumulative deterioration with resultant ponding.

The principal effects of synthetic detergents on the activated sludge process are foaming, floc agglomeration, and carry-over in activated sludge units (55). Such conditions have been experienced at various treatment plants. A report from the Batavia, Ill. (4), plant describes violent frothing in the aeration units.

Goldthorpe and Nixon (24) found that extended aeration periods were necessary when synthetic detergents were present. These workers also indicated a slight dispersal of floc which was not reversed after 24-hr. aeration (23).

Paper Mill

Paper wastes may reduce the efficiency of treatment because of the excessively high dissolved and colloidal organic content and strong alkaline properties. Treatment of sulfite liquor should never be attempted at a municipal sewage plant, as the chemical constituents will upset any treatment process (48). Southgate (63) examined a mill at which the waste waters were treated in a percolating filter. The liquid was so alkaline that no living organisms existed in the filters and substantially no purification was achieved.

Sawyer (56a), by means of several experiments, found that the activated sludge treatment of calcium base sulfite liquor sewage mixtures, containing 1 to 6 per cent of waste sulfite liquor, produced B.O.D. reductions as high as 95 per cent. Very little color removal was affected. When the sewage contained in excess of 6 per cent of neutralized waste, the activated sludge became too heavy to be kept in suspension with normal amounts of air. Experiments with magnesium base sulfite liquor showed a tendency to bulk when more than 2 per cent of the waste was used. B.O.D. removal was very poor. According to Sawyer, the B.O.D. removal was slowed down when greater concentrations of waste sulfite liquor were treated by the activated sludge process. This is attributed to the same limiting factors which inhibit biochemical oxidation, such as the lack of enough mineral elements to maintain normal rates of biological oxidation and metabolism. Free sulfur dioxide, and, possibly, loosely combined sulfur dioxide in the sulfite waste liquor, inhibit the growth of microorganisms in high-rate trickling filters and should be removed, state Tyler, Maske, and Brewer (71).

Coke and Gas Works

Key and Etheridge (37) have reported at length concerning the difficulty of treating gas works and coke liquors. The presence of phenols, higher tar acids, thiosulfate, and thiocyanate in spent liquors, as well as sulfide in the ammoniacal liquors, is of importance. Experiments with activated sludge showed the order of increasing difficulty of oxidation to be phenol, thiosulfate, catechol, thiocyanate, and sulfide. Additions of more than 5 per cent of spent liquors were detrimental. Liquors from coke ovens and gas works, when treated with sewage in comparatively small portions, may considerably increase the oxygen demand of the mixture and may lead to difficulty in the operation of biological processes of treatment usually employed (64). Stewart (68) reports that gas plant waste, from which only the tar had been removed, interfered with the efficient operation of the trickling filter plant at Fargo, N. Dak. Studies indicated that the phenol was

not responsible; suspicion was directed towards the tar acids and residue, which tend to accumulate on the rock film and produce sloughing by destroying the bacterial flora. The gas liquor, which contains phenol, cresol, catechol, quinone, and other higher tar acids, kills the aerobic bacteria and organic growths, thus making the activated sludge unable to ferment and decompose the coagulated impurities (59). In addition, as the quinone and catechols have strong affinities for oxygen, sewages containing these toxic substances consume large quantities of oxygen and produce underaerated, putrescible effluents for discharge. Results obtained by experiment show that sewage containing more than 0.3 per cent of gas liquor is difficult to treat by activated sludge alone. At Lancaster, Pa. (61), overflow of phenolic waters from a gas works to public sewers disrupted the action of the activated sludge plant.

Phenol

Kalabina and Rogovskaya (35) have found that phenol concentrations up to 3 g. per l. could be used as a source of carbon by certain bacteria. The higher the phenol concentration, the more sewage must be added to enable bacteria to work. Optimum rate is at concentrations of 0.5 to 1.0 g. of phenol per liter. Phenol is oxidized very rapidly in aeration tanks, at a rate of 120 p.p.m. per hr. with 2.5 g. of activated sludge and active aeration. It may, therefore, upset the normal process by its activity and toxicity. The nitrification is cut to 33 per cent of normal in earlier stages of phenol oxidation (3). Dickerson (15) reported the successful treatment of waste containing as high as 5,000 p.p.m. of formaldehyde by high rates of recirculation on a trickling filter. He reported later the operation of a full-scale high-rate trickling filter system for the treatment of wastes containing formaldehyde. Application to the filter of formaldehyde concentrations up to 360 p.p.m. did not decrease the efficiency of removal. A maximum removal of 28 per cent was obtained, calculated on the basis of formaldehyde concentration applied after high dilutions of the waste with the effluent from the filter. On the basis of the waste itself, the formaldehyde content was reduced from 800 p.p.m. to 167 p.p.m. by recirculation and filtration, or a reduction of nearly 80 per cent.

Volatile Solvents

Heukelekian and Schulhoff (26) found that many volatile solvents inhibited bacterial growth. Benzene at 10 ml. per l. had a definite inhibitory effect, noticeable even with short periods of contact. After 24-hr. contact with carbon tetrachloride, the reductions in bacterial number were considerable with 0.5 ml. per l., and even greater with 1.0 ml. per l. dose. Results with gasoline and kerosene were similar, but not as great as with benzene and carbon tetrachloride.

Other Organic Compounds

From the work of Placak and Ruchhoft (50) it is evident that some organic materials, especially those containing SH, CHO, or CN groups, are definitely detrimental to sludge and are not oxidized. Compounds such as urea are simply hydrolized. Organic acids produce the smallest yield of activated sludge, and carbohydrates the largest, with alcohols and amino acids intermediate in sludge production.

Inorganic Wastes

Inorganic wastes include acids, alkalies, and heavy metals. They are to a great extent germicidal, either because of an actual poisonous effect or because of their acidic or basic qualities. They frequently contain chemicals which produce large amounts of sludge when neutralized and oxidized (37). A re-

port by the Allegheny County Sanitary Authority (2) gave the following concentration limits for toxic and deleterious waste in composite sewage for secondary treatment: pH 6.5, total iron 5.0 p.p.m., copper 1.0 p.p.m., chromium 3.0 p.p.m. and cyanide 2.0 p.p.m.

Lime Waste

Coburn (11) reported that the lime wastes from a carbide plant upset the activated sludge treatment plant at Salem, Ohio. It caused the sludge to bulk, interfered with the sedimentation of activated sludge solids, and rendered the effluent unsatisfactory.

Paint Manufacture

Paint manufacture wastes contain antiseptic and poisonous materials. If the metallic poisons, such as lead compounds and arsenic, produced by the paint industry are present in sufficient quantities, they may establish a condition of toxicity with resulting retardation of biological activity (70). The wastes from a paint manufacturing plant containing copper, arsenic, and lead compounds interfered seriously with the operation of the activated sludge process at the Calumet sewage treatment works of the Chicago Sanitary District (11).

Explosives Manufacture

Of the waste liquors from T.N.T. factories, the most difficult to treat are those from washing and sulfiting of the final product (57). The waste liquors, which are dark red and have a pH of 1 to 3, give a high value of oxygen absorbed in the permanganate test, but absorb very little oxygen in the test for B.O.D. When diluted with water they interfere with the determination of D.O. by the Winkler method. They have an adverse effect on treatment of sewage by activated sludge and biological filtration.

Metal Pickling

Unless present in large quantities, pickling liquors are not toxic. However, acid pickling liquor, reports Siebert (60), cannot safely be admitted to public sewer systems or sewage treatment works since it compacts sludge, clogs trickling filters, and causes disturbances of reaction in activated sludge systems. Stooff (69) states that when iron metalworking and pickling liquor wastes are treated with domestic sewage in municipal disposal plants, an increased amount of sludge results, a longer retention period is required, and the biological purification may be completely checked. Pickling liquors consist largely of sulfuric acid and ferrous sulfate, which may completely upset any sewage treatment plant. When the Worcester, Mass. (40), trickling filter plant experienced a sudden increase in acid iron waste, there was considerable difficulty in drying an abnormally heavy growth on the surface of the filters. The iron content of the effluent had increased considerably; the pH averaged about 6.5. The D.O. and nitrate nitrogen content of the effluent of the trickling filter decreased. The stability of the filter and the final effluent decreased to about 50 per cent because of pooling caused by the growth. After several months it improved only slightly from 60 to 65 per cent. The filters were rebuilt in 1948 because of the clogging by iron wastes (9). Acid iron wastes also clogged the trickling filters (11)(39), increasing the suspended solids 75 per cent and the oxygen consumed 100 per cent over the normal sewage. Air diffuser media have been clogged by iron wastes at the Calumet plant of Chicago. Ellms (21) reported that the acid iron pickling liquors have played havoc with biochemical processes at Cleveland, Ohio.

Other difficulties may also arise because of pickling wastes (44)—for example, sulfates may be reduced to sulfides, causing foul odors and corrosion.

The action of acid on sludge causes particles to rise to the surface of sedimentation tanks. It encourages the growth of filamentous organisms, and the low pH inhibits the growth of organisms necessary to biological treatment (70).

Metal Plating

Brass, copper, and electroplating wastes are toxic and inhibit bacterial growth because of their ingredients, which include copper, zinc, nickel, chromium, acids, and cyanide. The effect of copper-plating waste was shown clearly at the Muskegon Heights, Mich., activated sludge treatment plant. According to Hurwitz (29), the activated sludge took on a grayish, sickly appearance and sour odor; the B.O.D. of the secondary tanks increased from 8 to 22 p.p.m. Examination of sludge revealed presence of copper in appreciable amounts. Chromium-plating wastes have a precipitating action on sewage, the chief effect being a colloid flocculation, with nitrogenous matter showing a higher than proportionate removal, according to Monk (45). At a small English filter bed treatment plant (67) it was found that chromium-plating waste with chromium concentration ranging from 3.5 to 67.5 p.p.m. in the raw sewage stopped the biological action in the filter beds entirely. No life could be detected by microscopic examination of the filter media. Cyanide wastes from metal plating are toxic to biological activity when present in dilution as low as 1 p.p.m. (61)(48). Ridenour and Greenbank (52) worked on the tolerance limiting concentrations of polysulfide-treated carburizing, copper-plating, and zinc-plating wastes before the activated sludge process is seriously affected. The carburizing salt bath may contain 10 to 60 p.p.m. NaCN, 30,000 to 50,000 p.p.m. NaCNS, and excess calcium polysulfide. The copper-plating solution may contain as high as 100 p.p.m. NaCN, 175,000 p.p.m. NaCNS, and excess polysulfide, besides a quantity of copper. The limits of tolerance are summarized in Table I. The sodium cyanide, although showing toxicity, was not as destructive as expected. Nitrification was depressed, but not completely destroyed, at 40 p.p.m. of NaCN. The limit of tolerance for polysulfide was quite high. Nitrification was unaffected until 1,000 p.p.m. of waste were added. Ridenour (53) studied the tolerance limits of alkali-chlorine treated carburizing, copper-plating, and zinc-plating wastes. The untreated metal-plating solution contained NaCN (5 per cent cyanide), caustic soda, and the metal cyanides. The carburizing solution consisted of NaCN (2.5 per cent cyanide) and the chlorides of barium, sodium, potassium, and strontium. The solutions were treated with sodium hydroxide and chlorine. Table II gives the tolerance limits. It was concluded that the alkali-chlorine treated wastes are toxic to aerobic sewage

TABLE I.—Limit of Tolerance of Activated Sludge Treatment for Polysulfide-Treated Waste

Waste Solution	Nitrification		Suspended Solids Removal Affected (p.p.m.)	Sludge Settling Affected (p.p.m.)
	Affected (p.p.m.)	Destroyed (p.p.m.)		
Carburizing	500	2,200	>2,200	>2,200
Copper plating	500	1,200	>1,200	>1,200
Zinc plating	500	1,200	>1,200	>1,200

TABLE II. Tolerance Limit of Activated Sludge Nitrification for Alkali-Chlorine Treated Wastes

Waste Solution	Nitrification			
	Affected (p.p.m.)		Destroyed (p.p.m.)	
	Whole	Settled	Whole	Settled
Carburizing	2,000	4,000	5,000	6,000
Copper plating	2,000	4,000	4,000	6,000
Zinc plating	3,000	6,000	6,000	9,000

treatment methods, but a relatively high concentration is tolerable in sewage before the efficiency of process is seriously impaired.

Cyanide

When cyanide is received in sewage treatment plants, states Dobson (17), it not only interferes with both aerobic and anaerobic processes, but also, if chlorinated, may yield an extremely noxious gas. Cyanide wastes interfered with the operation of the Mineola, N. Y. (1), sewage treatment plant. Nolte and Brandt (47) attempted to determine the effect of the presence of cyanogen on biological treatment with activated sludge. The test solutions contained calcium butyrate, tap water, phosphorus, and nitrogen salts, and an increasing amount of KCN. They used the "Magdeburg P Process" in an intensively aerated Sierp basin. With KCN concentration as low as 5 p.p.m. the protozoa, except *Vorticella*, received a shock from which they soon recovered. With step by step addition up to 22 p.p.m., the same effect was observed. Bacteria multiplied vigorously. At at initial concentration of 62 p.p.m. KCN, the effluent was free of both cyanide and butyric acid. With higher concentrations of KCN, cyanide appeared in effluent. All life higher than bacteria was destroyed at 80 p.p.m. At concentrations up to 330 p.p.m. the activated sludge was normally replenished and the butyric acid was quantitatively decomposed. Higher concentrations gave only partial decomposition. It was concluded that previously reported difficulties in the biological treatment of cyanide containing wastes (usually from galvanic plants) must, therefore, be due primarily to the simultaneous presence of toxic heavy metals and less to the cyanide content of the wastes.

Results of the work by Lockett and Griffiths (41) showed that a concentration of 5 p.p.m. cyanide (as HCN) in the sewage added to activated sludge had a marked inhibitory effect on the purification process, even though much cyanide was blown off as HCN. It was determined that 1 p.p.m. cyanide (as HCN) in the sewage will retard the rate of building up of a good activated sludge. There are indications that cyanide in low concentrations has an inhibitory effect, rather than a lethal effect, on bacterial life. Coburn (13) reports that a concentration as low as 1 p.p.m. of cyanide is toxic to biological activities. Interference with nitrification on percolating filters was observed by Pettitt and Thomas (49) when there was a HCN concentration of 2 p.p.m.; at 4 p.p.m. the B.O.D. of the filter effluent was appreciably increased. At concentrations up to 10 p.p.m., 98 to 100 per cent of cyanide was destroyed by the filter. A sudden addition of 30 p.p.m. to the sewage inhibited nitrification and led to an effluent of extremely poor quality.

Chromium

Monk (45) added various concentrations of CrO_3 to suspensions of *B. aerogenes* in order to estimate the chromate strength which might be allowed in sewage without harm to biological purification processes. From the results (Table III) he concluded that 50 p.p.m. of CrO_3 may be considered a safe figure for chromate concentration in sewage arriving at treatment works.

Jenkins and Hewitt studied the effect of chromium compounds on the operation of trickling filters (33) and the activated sludge process (34).

TABLE III.—Action of Neutralized Anodizing Waste on *B. Aerogenes*

Per Cent Survivors in	CrO_3 Concentration (p.p.m.)			
	500	250	50	10
½ hr.	39	47	66	91
1 hr.	25	27	64	91
2 hr.	22	24	54	84
4 hr.	0	0	1	6
24 hr.	0	0	0	0

They found that in the operation of trickling filters 1 p.p.m. of chromium in the form of potassium chromate had a slight effect, 10 p.p.m. appreciably reduced the quality of effluent, and 100 p.p.m. reduced nitrification by 66 to 78 per cent and produced an effluent containing twice as much organic matter as the effluent from the control filter. In the activated sludge process they found that in the presence of 2 p.p.m. of chromium as chromate the nitrification begins to deteriorate. The process is arrested by addition of 3 or 4 doses of sewage containing 5 p.p.m. of chromium as chromate. Higher concentrations accelerate the process of inhibition. The ability of activated sludge to oxidize organic matter and to flocculate dispersed solids is reduced in the presence of chromate. It was found that respiratory activity, as determined by the amount of carbon dioxide evolved on aeration, was greatly depressed by addition to sewage of 10 p.p.m. of chromium as chromate. The process of nitrification may be arrested, sometimes for a long period, without actually killing the organisms. Prolonged aeration of a chromate treated sewage seems to be the most effective way of restoring nitrifying activity. Chromium salts, such as chrome alum, are relatively harmless towards nitrification and removal of organic matter by activated sludge. Therefore, it should be possible to render harmless a waste liquor that contains chromate by means of reduction to the chromium salt.

Well (73) obtained poor settling of activated sludge and unusually low efficiency of treatment (15 per cent removal of total solids) because of chromium wastes sufficient in amount to color the aeration liquor. The chromate caused the D.O. values to be high and interfered with the bacterial life. Spencer (66) described a trickling filter plant in which biological action was stopped by chromates, the concentration ranging from 3.5 to 67.6 p.p.m. as chromium. Ross (54) reported that the activated sludge plant at Richmond, Ind., handled without difficulty 1 p.p.m. chromium of chromate wastes. The Tallmans Island activated sludge plant in New York City (20) received during a 2-day period 430 p.p.m. chromate (as Cr) with a pH of 4.2 the first day, and 1,440 p.p.m. chromate (as Cr) with a pH of 4.0 the second day. As a result, the D.O. increased and remained at a much higher level, even 14 days later, than for some time previous. It is believed that this may be caused by reduction in activity of organisms, as the air ratio remained practically constant. Microscopic examination of the activated sludge showed almost complete disappearance of filamentous bacteria, such as *Sphaerotilus*, which had been present in moderate amounts. The stalked ciliates also decreased in number after a few days. Before the discharge of chromate wastes, the free ammonia ordinarily decreased from 30 to 15 p.p.m. in passing through the aeration tanks, and the effluent contained about 1 p.p.m. nitrite and 2 p.p.m. nitrate. Immediately after the addition of chromate there was no reduction in free ammonia and practically no nitrites or nitrates were produced. In 10 days the nitrites approached normal values. The plant effluent was turbid for several days, probably because of dead organisms, but it cleared up with the re-establishment of nitrification. According to Southgate (65), wastes containing chromate caused excessive accumulation of film on rocks, and reduced the efficiency of biological treatment when in concentrations as low as 1 p.p.m. Coburn (12) (13) states that chromium in the hexavalent form is toxic, and when present in sufficient quantities will kill organisms in filters or activated sludge. He further states that the trivalent form causes very little trouble biologically.

Copper

Copper wire works and other copper wastes discharged into the sewer precluded the use of the activated sludge process for the treatment of sewage at New Haven, Conn. (11). Dodge (18) states that the Ann Arbor, Mich., sewage treatment plant received a heavy discharge of copper waste from an unknown source. This increased the suspended solids from 225 p.p.m. to 625 p.p.m. This same type of waste continued to arrive for 4 days, with the result that the aeration process was seriously retarded. Sierp and Fransemeier (62) consider, from laboratory experience, that the safe maximum concentration in sewage to be treated by the activated sludge process is about 1 p.p.m. of copper. Kalabina (36) found that 0.5 p.p.m. of copper sulfate as copper was toxic to all microorganisms, and 0.1 p.p.m. was toxic only to bacteria. Rate of ammonia formation is retarded if copper is above 0.5 p.p.m. Nitrification is retarded noticeably by concentrations above 0.5 p.p.m. copper. He concluded that waste water for biological treatment must contain not more than 0.1 p.p.m. copper. Southgate (65) states that wastes from the pickling of copper slow down or stop biological action in trickling filters.

Lead

Experiments performed by Kalabina (36) shows that the toxicity of lead is moderate, and noticeable only for a short time at lead concentrations above 1 p.p.m. Concentrations above 0.5 p.p.m. retard the growth of protozoa and nitrification, and those above 0.1 p.p.m. were toxic to biochemical oxidations. He concludes that wastes for biological treatment should not contain more than 0.1 p.p.m. lead.

Boron

At Pomona, Calif. (51), it was discovered that the boron used in the washing of citrus fruit upset the activated sludge plant. The activated sludge process was affected by a concentration as low as 0.05 p.p.m. boron. The sludge is prevented from settling. It took 2 to 3 hr. after the boron flow stopped before the sludge settled. One to two days were required for recovery of sludge if 1 p.p.m. was present.

Nickel

Hill (26a) reported that nickel salts exert a toxic effect on activated sludge either by adsorption and/or actual poisoning of certain essential microorganisms in the sludge. Concentrations of nickel between 1 and 3 p.p.m. definitely inhibited nitrification by activated sludge, but had no apparent effect on clarification. Concentration of 6 p.p.m. has a threshold effect, whereas 10 p.p.m. has a very pronounced effect.

Other Inorganic Substances

Using phenol with a standard value of 1, the harmful effects of other substances are: sodium sulfite, 6.5; sulfurous acid, 9.7; caustic soda, 20.4; sulfuric acid, 167; copper sulfate, 218; and chlorine, 430 (6).

Sulfides in sewage exert a detrimental influence on biological treatment, either by trickling filter or activated sludge. This is confirmed by the upsetting of the sewage treatment plant at Ft. Worth, Tex., by waste containing large quantities of mercaptans and other sulfur compounds.

Sartorius (56) reports that large amounts of carbon have a detrimental action on bacteria.

Nesmeyanov (46) added various iron and aluminum compounds to activated sludge. The addition of $FeCl_3$ or $Fe_2(SO_4)_3$, in amounts from 8.7 to 500 p.p.m. as iron, to sewage mixture produced a retarding effect on the oxidation, particularly of nitrogen compounds. Aluminum salts gave a similar result. The action was not at-

tributed to the iron or aluminum, but to the change in acidity resulting from hydrolysis.

Dawson and Jenkins (14) utilized the manometric technique to study the effect of a great number of inorganic and organic compounds on the oxygen utilization of activated sludge. The period of observation was limited to a maximum of 2.5 hr. of a single initial addition. The following inorganic cations were studied: zinc, cadmium, copper, mercury, nickel, aluminum, lead, manganese, calcium, barium, ferrous iron, and ferric iron. Of these, zinc, copper, chromium, cadmium, and nickel were found to be among the most toxic substances. Anions such as borate, phosphate, sulfide, sulfate, chloride, nitrate, and iodide had little effect. Chromate, chlorate, thiocyanate, and cyanide were toxic at various concentrations. Nitrite was found to have a toxic effect. Thiosulfate, sulfide, and sulfite had no inhibiting effect, except the latter two (at higher concentrations) increased the oxygen demand. Some toxic cations were found to have an additive effect when used in combinations, whereas others tended to neutralize the effect of one another. Almost all of the organic substances tested increased the oxygen demand. In this category belong the pentoses, hexoses, disaccharides, polysaccharides, sugar, alcohols, lipoid compounds, amino acids, and proteins. Cellulose and lignin did not increase the oxygen demand of the activated sludge. Glycerol was more rapidly oxidized than fatty acids; amino acids were more rapidly oxidized than peptones. In general, the higher the nitrogen content of the amino acids, the lower was the increase in oxygen uptake.

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III. EFFECTS ON NATURAL PURIFICATION OF STREAMS—DEOXYGENATION

In searching the available literature, there are numerous papers dealing with surveys of river systems showing the effect of pollution on the streams. Little deoxygenation data are given, as the authors have not made, or combined, the necessary close measurements of discharge and time of water flow with the data collected at the various sampling stations in question.

Baity and Bell (1), in their studies on the reduction of the B.O.D. of sewage by chlorination, found that by adding chlorine to sewage effluents, so as to have a 10-min. chlorine residual of at least 0.9 p.p.m., the deoxygenation rate of the material will be retarded until the material has progressed downstream to a point where there is greater dilution. This particular work was done on a small receiving stream where the load on the stream at the sewage outfall would have been too great for the stream discharge at that point.

Chubb and Merkel (2) report that the acid wastes on the Schuylkill River have the effect of delaying the deoxygenation process on the domestic and industrial wastes which enter the river. The upper reaches of the Schuylkill drain an area containing many abandoned coal mines, which contribute highly acid wastes. This acid water then receives domestic sewage and industrial wastes and carries them downstream in a preserved or pickled condition until the river flows through a limestone section where the acid is neutralized and a favorable environment is present for normal deoxygenation processes.

Felegy *et al.* (3) state that in the anthracite regions of Pennsylvania the highly acid mine wastes often appear to be beneficial because of the neutralizing action on the highly alkaline sewage and industrial wastes discharged into the streams. This, as is pointed out, applies especially to the drainage basins of the Lehigh, Schuylkill, and Susquehanna Rivers.

Kittrell and Churchill, in an unpublished report, have found some inhibiting effects on deoxygenation rates in a river in Tennessee. The inhibiting agents are copper and/or zinc. Samples collected on the river above sources of pollution have normal deoxygenation coefficients, but those samples collected below industrial wastes (containing copper and zinc) released by rayon plants show very low B.O.D.'s. The 40-day B.O.D.'s run in the laboratory from the lower stations show that deoxygenation is practically nil for 2 to 3 days, after which the k_1 value changes daily for 5 to 10 days, after which there is a uniform k_1 rate.

There are instances cited in the literature in which there are increased rates of deoxygenation, rather than inhibitory action. These also are worthy of mention.

Kittrell and Kochtitzky (4), in their report on natural purification characteristics, have noted that on the particular stream on which their survey was made the k_1 values in the stream section above pollution are greater than any previously reported for a stream. A table is presented showing the deoxygenation and reaeration calculations for several stations below the main sources of pollution. The source of pollution is both industrial wastes and domestic sewage. It is interesting to note that there is a wide and rapid

variation (2.26 to 0.017 at 20° C.) in the k_1 value as the water progresses downstream. These stream k_1 values are more than 10 times those obtained in the laboratory bottle studies.

Wisely and Klassen (5) have calculated the coefficients of deoxygenation for three reaches of the Illinois River. The major portion of wastes in this river are in the upper reach, which receives a large industrial load, principally from distilleries, yeast manufacture, corn products, and some paper mill wastes; only small quantities of domestic sewage are involved. The calculated k_1 values show a decrease progressively downstream in the following order: 0.276, 0.183, and 0.138. The deoxygenation rate is high in the upper, or polluted reach of the river, due to the effect of numerous sludge deposits.

A study made by Kalabina *et al.* (6) concerning the effects of non-ferrous toxic substances on self-purification of reservoirs, indicates that 0.1 p.p.m. of copper and 1 p.p.m. of lead is toxic to aerobic bacteria.

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IV. EFFECTS ON THE MICRO-FLORA AND MICRO-FAUNA OF STREAMS

Over the past 25 years special biological studies have been increasingly used to direct the design of waste treatment processes and stream improvement programs. The general biological survey is still employed as a normal part of fishery management and conservation investigations, but the demand for specific and quantitative information on the action of wastes and their alterable components has stimulated a variety of new approaches to the development of workable standards of water quality. In particular, the effect of wastes on the whole economy of waters as a basic working concept in resources development has gained stature among sanitary engineers, as well as among aquatic biologists. A large amount of useful information, in the form of data on the toxicity of wastes and pure chemicals on fish life, is already available and active steps have been taken to standardize methods of testing and reporting future observations. Somewhat less attention has been paid to the effects of wastes on the smaller animals and plants; on the free, suspended plankton; and on attached or embedded bottom micro-fauna and micro-flora.

A much wider and intensive use of researches and observations concerning the action of wastes and treated effluents on the small animals and

plants may be expected. Virtually all of the heavily fished waters are stocked, and the maintenance and growth of the inland recreational fisheries depends on long sequences of supporting food organisms. The nature of stream-bottom animal communities is recognized as an excellent guide to the fitness of the flowing water; slow, subtle changes, or waves of pollution that do not show in periodic chemical tests, are reflected in these populations. Finally, the biologically active surfaces responsible for self-purification and recovery consist in large part of mixed groups of physiologically aggressive bacteria, protozoa, algae, worms, mollusks, crustaceans, and insect nymphs and larvae that hasten the loss of energy from polluted waters by their activities.

Reviews and Methods

The most generally used recent contribution to the action of toxic wastes on aquatic animal life has come from outside the sanitary engineering profession. This is one of a number of bulletins published by the U. S. Bureau of Fisheries (now the U. S. Fish and Wildlife Service). It is popular because of the convenient tabulations and summaries of the toxicities of common chemicals found in industrial wastes to fresh water fish and smaller test animals, and because it presents a clear statement of the relation that the qualities of receiving waters bear to the toxicities of discharged wastes (14). The data reviewed therein have often been applied to determine dilution limits without regard for the conditions of hardness, conductivity, pH, turbidity, and temperature that are presented. The role of these factors is further emphasized in a later bulletin (17), which is a manual of analytical methods for water, but contains sections on the toxicity and physiological action of waste components.

The toxicity studies reviewed in both bulletins refer primarily to fish life. Of the smaller animals, references are most frequent to tests with the water flea, *Daphnia magna*, which has been used extensively. There are a few references to toxicity values against the fresh water copepod, *Cyclops*. These small crustaceans are most prominent in the life chains of ponds and lakes, and are less common in running waters. *Daphnia* are especially adaptable to quantitative laboratory toxicity tests. Their sensitivity to metals, and the ease and low cost of maintaining stocks for long series of tests make it a favorite animal.

Tests for toxicity of pure substances using *Daphnia* have been standardized and a considerable background of information on the comparative activity of chemicals commonly found in industrial wastes is available. Anderson (1)(2)(3) has studied the conditions of testing and has modified the methods used by Ellis to increase the statistical reliability of the data; he has added two important improvements—the standardization of age and nutrition of the animals, and the use of end-points based on per cent mortalities against time. In the first of two studies, Anderson (2) compares the toxicity of 42 pure chemicals, including 4 inorganic acids, 8 organic acids, 25 inorganic salts, and 5 organic solvents. The end-points in this study are based on molar concentrations required to immobilize 50 per cent of the animals in 16 hr. Although this permits a good estimate of relative toxicities, it does not establish levels of tolerance. The data are further limited to clarified Lake Erie waters and, although these have useful applications, the action of chemicals in waters of different pH value, hardness, turbidity, and organic content cannot be developed.

In Anderson's second study (3) the method was revised to give higher sensitivities. This involves extending the time of exposure to 48 hr., an

interval that insures the moulting of test *Daphnia*, and the inclusion of this critical period in the animal's responses. The end point was taken as the concentration required to immobilize 50 per cent of 10 test *Daphnia* in 48 hr. The second study systematically compares the toxicity of 38 sodium salts, giving data on anions.

The standardization of *Daphnia* tests promises to be valuable, not only for demonstrating the toxicity of unknown materials, but also for establishing working dilutions. Under laboratory conditions *Daphnia* appear to be more sensitive to common pollutants than most fish (1)(16). During the past war, extensive investigations on the possible adverse effects of DDT and other mosquito larvicides on pond life utilized *Daphnia* tests (26).

Using *Daphnia* as a test animal representative of fish food organisms, the minimum lethal concentration of the toxic components of kraft pulp mill wastes were established (52). Data obtained indicated that the species of *Daphnia* tested were no more sensitive to these poisons than were the species of fresh water minnows. The minimum lethal concentrations of the various components of kraft mill wastes to *Daphnia* are given as follows:

Compound	Min. Lethal Concentration (p.p.m.)
Sodium hydroxide	100
Sodium sulfide	10
Sodium sulfate	5,000
Sodium carbonate	300
Sodium sufite	300
Hydrogen sulfide	1
Methyl mercaptan	1
Crude sulfate soap	5 to 10
Sodium salt of fatty acid fraction of sulfate soap	1
Sodium salt of resin acid fraction of sulfate soap	3

Insect larvae were found to be not as susceptible to toxic substances in kraft mill wastes as *Daphnia* (53). *Chironomus* was very resistant to all materials tested. The minimum lethal concentrations of various ingredients of kraft mill wastes for insect larvae were:

Compound	Min. Lethal Concentration (p.p.m.)
Sodium hydroxide	125 to 1,000
Sodium sulfide	2 to 1,000
Methyl mercaptan	50
Crude sulfate soap	50
Resin acid soap	50 to 100

The results for insect larvae were more irregular than those for *Daphnia*. In general, however, if environmental conditions are favorable for *Daphnia*, the insect larvae will not be harmed.

Domestic, Organic, and Agricultural Pollution

The enrichment of surface waters through addition of organic matter and materials yielding available nitrogen and phosphorus is an especially insidious form of pollution. It shows itself most strikingly in the more popular lake districts, where increased recreational and business activity has accelerated the progress of unfavorable changes.

Hasler (25) has presented a careful summary of the deterioration of aesthetic, fishing, and recreational values of 39 well-known lakes that have been subjected to steady fertilization by domestic and agricultural drainage. The changes reported are, for the most part, recorded within the last few decades, and represent only those cases documented by good chemical and biological data. The condition is much more general. The series reviewed includes Finnish, Alpine, Swedish, English, and American lakes.

The condition grows not from introduction of toxic materials, but from the production of adverse physical, chemical, and biological limits within the waters themselves. The bottoms become muddy; blue-green plankton algae dominate, with *Aphanizomenon* a common component; and troublesome water blooms are frequent. The D.O. content of the water reflects these

changes by showing greater variations. The recreational and commercial fishing values decline.

This form of accelerated "aging" (eutrophication) of lakes is also associated with enrichment by other organic wastes, such as those derived from flax retting, dairy, paper pulp, and distillery industries. Progressive eutrophication is a consequence of increasing additions to and production of organic matter in the fertilized lakes. The rising organic content of the bottom mud produces strong reducing conditions and low D.O. in the deep-water strata. The dense phytoplankton growths bring about wide day to night fluctuations in the D.O. content of the producing zones, through alternating dominance of photosynthesis and respiration processes. The shores become muddy and weed bearing (25).

An abundance of a restricted group of phytoplankters is characteristic of eutrophic lakes and fertilized ponds. A soup of *Scenedesmus, Chlamydomonas, Microcystis,* and *Aphanizomenon* develops. The golden yellow algae, such as *Synura* and *Chrysococcus,* are uncommon (51). The most significant limit to the production of a variety of larger animals that might utilize the abundant organized material of the water and mud is the depletion of oxygen near the bottom, and in the water generally, during the night or during periods of overcast weather.

Because most chemical measurements of polluted streams and lakes are taken during daylight hours, eutrophic diurnal D.O. excursions are not generally appreciated. Biologists have long recognized the phenomenon as a limiting condition. Further demonstrations, such as that given in the direct study by Rudolfs and Heukelekian (43), may drive it home in the profession.

The steady organic enrichment of bottom muds is characteristic not only of fertilized lakes and ponds, but also of impoundments generally. Low-oxygen tolerant debris feeders like midge (*Chironomus*) larvae and aquatic earthworms (*Tubifex*) become very abundant in the bottom. The normal bottom populations of flowing, aerated waters (mayfly and stonefly nymphs, caddisfly and beetle larvae, amphipods, hellgrammites, most snails and mussels, and crayfish) disappear. A few forms like leeches, *Pisidium variable, Musculium socuris,* and highly tolerant snails of the genus *Stagnicola,* together with *Syrphus* fly larvae, may become more evident on the mud-gel that they seem to prefer (19)(24)(27)(29)(46).

The response of lakes and lake-like reaches of slow-flowing rivers during the stages of recovery from pollution is quite different from that of rapid streams. Pollutional enrichment of lakes, especially, produces a continuous accelerated aging, with abundant growth of more limited plankton species, and accompanying greater diurnal variations in D.O. content. Waterblooms and fish catastrophes become more frequent. The recovery zone of enriched flowing streams, on the other hand, may be marked, as Brinley's surveys of the Ohio River system have shown, by a greater abundance and variety of plankton forms (4). Ludwig (37) finds that bottom invertebrates follow the same pattern; in the zone of recovery the animal population grows in variety and volume over that of the clean water stretches preceding the polluted belt. Eddy's survey of plankton forms on the Sangamon River (11) gives good examples of this effect.

Impoundments themselves favor more lake-like animal and plant forms. River bottom animals, such as mayfly and stonefly nymphs, decrease and *Chironomus* larvae replace them (46). The normal drift population of the river tends to accumulate in the shore zone near the entrance to the impoundment; it rarely follows the stream through. Its persistence depends on

fortunate physical conditions. Some members are buried in the debris of delta formation; wave action and exposure on the shore during drawdown are also unfavorable (10).

The plankton forms, which are normally much more significant in lake or impoundments, suffer a different fate when they are discharged into the rivers below. An appreciable fraction is adsorbed on films on the stream bottom, on shore weeds and plants, and on other surfaces. This material is lost from the water volume proper, and an analysis for plankton only would give a misleading measure of the biological activity of the outflowing waters (8).

It is interesting to note that the numbers of insect larvae, worms, mussels, snails, and other bottom fish food organisms depends on the stability of the substrate; sands and shifting gravel harbor few organisms, larger stones and rubble produce more. The productivity of bottoms may be increased by the deliberate addition of fixed structures (40)(49).

The moral here is that the physiography of a stream determines its behavior under conditions of pollution and recovery.

The mechanical and biological action of silts is at present receiving major attention from conservation agencies. Ellis's (13) observations and experiments on silting of the Mississippi River system graphically demonstrate the wide variety of adverse factors that operate against small clean-water plants and animals in a silted environment. Rising turbidities exclude light and reduce the production of phytoplankton and bottom algae; the settling silt further reduces the living and dissolved organic load of the water by adsorbing it and translocating it to the bottom. The comparatively slow, anaerobic bottom processes permit the accumulation of high concentrations of organic matter in mud. In this unstable, oxygen free, reducing substrate, most species of fresh-water mussels and snails perish.

The conventional training of sanitary engineers has emphasized the use of plankton organisms as indicators of water condition. In rivers and polluted streams, however, the composition of the small animal bottom population and of the attached films is a better guide. These populations integrate the long-term biological conditions. Over a period of 10 years, Lackey examined several hundred plankton samples from many sources in a search for indicator species in the protozoan groups. Generally speaking, the tolerance of protozoa is great, and a very few are limited to strictly pollutional or strictly clean-water environments. Of these, *Anthophysa vegetans, Carchesium lachmanni, Euglena viridans,* and *Paramecium caudatum* are associated with organic pollution (33). These same large protozoa are common on sewage trickling filters. Generally, the golden-yellow algae or flagellates of the groups *Chrysomonidida* and *Cryptomonidida* decrease with pollution (34).

Carbohydrate-rich wastes are usually indicated in polluted streams by active growths of masses of the slime forming bacterium, *Sphaerotilus natans.* Masses of this "sewage fungus" are unsightly; they are frequently troublesome when carried with the current. *Sphaerotilus natans* has a very high rate of metabolism and requires steady feeding. It disappears rapidly when its energy supply is restricted (6)(41). For this reason, its presence may indicate active pollution by sugar-rich wastes.

The pollution of estuaries with sewage and organic wastes has long concerned shellfish operators and public health officials. Stabilized organic-rich bottoms favor the production of the edible soft clam, *Mya arenaria,* and where attachment is possible, the common black mussel, *Mytilus edulis.* Unstable, organic-rich estuarial muds,

on the other hand, are poor in bottom life (20) (21). Highly diluted organic wastes, such as those from the paper pulp industry, may favor the growth of estuarial plankton forms, but low dilutions inhibit their growth (18) (23) (50). Heavy pollution by oil well wastes also appears to inhibit the production of some brackish water diatoms, and to interfere with the normal feeding of oysters (22).

Acids and Alkalis

Neutralization of acid or alkaline wastes has become a general requirement for disposal of water-borne industrial wastes. Most of the desirable aquatic life exists over a fairly wide pH range, but natural fresh waters are only slightly buffered and their ability to resist shock loads is limited. Lackey (32) has studied the bottom and plankton populations of a series of strongly acid waters, where drainage of mine waters over a long time has permitted the establishment of adapted populations. The bottom populations were found to be notably restricted in the more acid zones, where the pH ranged from 1.8 to 3.8. Only species of *Gammarus, Corethra and Chironomus* larvae, and *Aedes* mosquito larvae were found. The plankton contained species of *Pleuromonas, Chlamydomonas, Chromulina,* and *Euglena.* Some species of *Oxytricha,* naviculoid diatoms, the alga, *Ulothrix,* and *Distyla* were also taken. Limited species of dragonfly nymphs of the genus *Libellula* have been found in less acid bottoms receiving mine drainage (pH 6.4 to 6.6), which appear to withstand the shock of short period, high acidities as well (47). These mine drainage streams are generally clear waters, free of toxic metals.

The neutralizing capacity of estuarial waters is a significant limit to acid pollutional effects. In the Curtis Bay region of Baltimore Harbor, which receives large volumes of steel pickling wastes, the excess base of sea water sharply restricts the zone of high acidity, beyond which the estuarine plankton production is normal. Within the acid discharge zone plankton is rapidly destroyed, and at its periphery the precipitate of ferric hydroxide mechanically carries down a large proportion of fine living stuff (39).

Toxic Metal Wastes

Knowledge of the action of toxic metal salts on small aquatic animals has grown in large part from experience in pollution from lead and zinc mining operations. The long drawn out investigations of Welsh rivers are classic. These have been summarized by Newton (38), who brought together a large number of reports and records lost during World War II.

The changes brought about by mining operations are of a complicated order; debris and rock dust bearing oils and flotation agents alter the bottom itself, and continuous or intermittent leaching from soluble deposited encrustations, or from abandoned operations, is a considerable factor. The larger part of quantitative information has been derived from laboratory studies and demonstrations, however.

Within the past 15 years the toxicity of zinc residues has received considerable attention. The high toxicity of soluble zinc salts to small plankton, crustaceans, and bottom life generally, was demonstrated by Ellis (12), Jones (31), Carpenter (7), Newton (38), and Davies (9). However, because of the difficulties in the analysis for zinc at low concentrations, and the attenuating factors of silt and hardness, it is difficult to establish tolerance thresholds from these investigations. Ellis (12) noted that plankton crustacea, mainly copepods and their nauplii, were killed by zinc sulfate solutions at 10 p.p.m. Zn, and that concentrations as low as 0.1 p.p.m. Zn retained their toxicity with longer periods of exposure. Davies (9) set minimum tolerances for pond snails (*Limnaea*

pereger), fresh water limpets (*Ancylostrum fluviatile*), and fresh water shrimps (*Gammarus pulex*) at 0.2 p.p.m. Zn. Mayfly nymphs (*Cloen simile*) tolerated concentrations only slightly higher (0.3 p.p.m. Zn). Water boatmen, stonefly and dragonfly nymphs and caddisfly larvae were comparatively tolerant, perisisting at levels below 500 p.p.m. Zn (7). The zinc-rich waters of Bear Lake, Idaho, bearing 0.65 p.p.m. Zn, killed species of *Daphnia* in three days (28). In the classic River Ystwyth investigations, the zinc-polluted reaches of the river—bearing from 1.2 to 1.4 p.p.m. Zn—are devoid of mollusca, oligochaete worms, and crayfish. On the other hand, nymphs of stoneflies, dragonflies, and mayflies, and the larvae of many blackflies (*Simulium*) were taken from the most heavily polluted bottoms. The insect fauna seems to be selectively limited by physical conditions of the rocky, swift river, devoid of vegetation, rather than by its zinc content (35).

It is interesting to note that these controversial waters are soft, naturally acid and acid bearing, clear, calcium-low waters, permitting high solubilities and activities of zinc salts. The toxicity of zinc sulfate for fish is markedly decreased by hardness, and specifically by calcium salts. It is possible that these factors may have general protective action against zinc (30).

The variability in toxicity of copper salts used for algae control is well-known. Residual copper is the most practical measure of anticipated algicidal activity. The toxicity of copper salts for the zooplankton and small animal bottom life is modified by the same factors that operate for zinc. Where copper sulfate is deliberately used to poison undesirable fish, levels that kill fish usually destroy the principal crustacean zooplankters, bottom insects, snails, and mussels. Leeches appear to survive. The insect population returns fairly rapidly after initial destruction, but the molluscan fauna regenerates slowly (45). The copper concentrations applied, and residuals maintained for fish poisoning, range about 3 p.p.m. Such residues kill virtually all phytoplankton (44) (45).

In some lakes previously treated with copper sulfate, a residue of soluble copper may be regenerated from the bottom with each fall overturn to reach concentrations that limit the developing small animal population. Riley has demonstrated such an effect in a Connecticut pond (42).

Investigations in the use of arsenic (arsenious oxide) as an aquatic weed killing agent have furnished information on the relative tolerance of freshwater organisms. Surprisingly, many species of mayfly nymphs tolerate relatively high doses of arsenious oxide, from 3 to 14 p.p.m.; their tolerance is even higher when absorbent debris is present. Damsel and dragonfly nymphs also withstand high concentrations, 10 to 20 p.p.m. arsenious oxide, under these conditions.

Chironomus larvae, on the other hand, have proven relatively sensitive to arsenious oxide, with mortalities at 1.9 p.p.m. This group tolerates 5 p.p.m. sodium arsenite. Large ciliate protozoa like *Colpidium*, *Paramecium*, and *Stylonychia* tolerate up to 3.5 p.p.m. arsenious oxide, as do some of the crustacean zooplankton. These concentrations of arsenious oxide are destructive to some blanket algae (48).

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V. EFFECT ON THE B.O.D. TEST

The review in this section is limited to those phases of the B.O.D. test dealing with the inhibitory effect of industrial wastes and compounds on the rate of deoxygenation. To put it differently, it is concerned with the use of the B.O.D. test as a tool for the detection of inhibitory substances on the oxidation of sewage and wastes, the effect of the addition of a compound on the oxidation of an organic substrate, and the effect of various concentrations of a waste on the B.O.D. values as measured by the dilution or direct absorption methods. It is not a review of the method or of the effect of variables, such as pH, seeding, type of dilution water, nitrification, etc. It concerns itself primarily with the effect of the nature and the composition of the substrate.

Theriault and Hammond (14) used the excess oxygen method to determine the effect of different concentrations

of tannery and strawboard wastes on the B.O.D. values. They found that with these particular wastes, within the range of concentrations which could be employed and within the limitations of the dilution method, the values obtained by different concentrations were in good agreement with each other.

Eldridge (1) studied the rate of oxidation of sulfite liquor, white water, milk wastes, and beet sugar wastes. He concluded that the rate of oxidation of each of the wastes is quite varied and, therefore, the total demand should not be calculated from the 5-day demand. It is not possible to derive an oxidation curve that would apply generally to trade wastes, because of the variation in the type and proportionate quantities of oxidizable materials. The same author (2) noted that when neutralized Steffens waste was diluted with seeded bicarbonate dilution water, increasing B.O.D. values were obtained with increasing dilutions. Similar results were obtained with white water. As sodium bicarbonate water was used in these experiments, the results obtained might be attributed to deficiency of nutrients, rather than to the inhibitory effect of the various concentrations of the wastes.

Gehm (3) obtained, for 1-day B.O.D.'s, 30 per cent of the 5-day demand for sewage, paperboard waste, de-inking washer waste, flax pulping waste, and combined kraft mill waste. Lower percentages were obtained for combined strawboard waste, sulfite waste liquor, and jute pulping waste.

Symons and Buswell (13) determined the B.O.D. of certain pure substances, such as lactose, starch cellulose, sodium palmitate, peptone, and sodium oleate. They found that only 70 to 85 per cent of the theoretical demand (calculated from the equation for complete oxidation) was exerted in 30 days.

Heukelekian (4) determined the toxicity of mercuric bichloride, copper sulfate, cobalt chloride, potassium cyanide, and sodium arsenate by determining the oxygen utilization (by the dilution method) of sewage with various concentrations of these materials. The same author, using the same technique, determined the effect of a number of organic compounds on the oxygen utilization of sewage. The direct absorption method (Sierp) was applied to the study of the oxygen demand of wastes and compounds, and the effect of such materials on the oxygen utilization (5). It was possible by this method to use concentrations of substrates higher than those that could be employed by the dilution method. The dilution and the direct methods, either singly or together, could be used to advantage to evaluate the toxicity of industrial wastes (6). Rogers (10) also used the dilution method for the determination of toxicity of various concentrations of phenol. The effect of copper on the B.O.D. of sewage, as determined by the dilution method, was noted by Scott (12), who reported that copper in as low a concentration as 0.1 p.p.m. gives lower values. Placak, Ruchhoft, and Snapp (9) reported that copper in the amount of 0.01 p.p.m. or greater, if present in an incubation sample, will prevent the determination of the true B.O.D. Chromates in amount greater than 0.3 p.p.m. Cr will give appreciably lower results than the true B.O.D. Experiments performed by Krieger and Moore (8) indicated that both hexavalent and trivalent chromium were toxic. Although both forms of chromium induced a B.O.D. lag with 1 p.p.m. concentration, the trivalent form showed more consistent inhibition as the chromium concentration increased. Hexavalent chromium reached a plateau in its effect on B.O.D. of sewage when its concentration was 3 p.p.m.; further increases to 10 p.p.m. had no significant effect on the inhibition.

Kalabina *et al.* (7) reported that 0.5 p.p.m. of Cu was toxic to all microorganisms and 0.1 p.p.m. only to bacteria. Lead (Pb) was toxic to biochemical oxidation of organic matter at 0.1 p.p.m., to flagellates and infusoria at 0.5 p.p.m., to nitrifying bacteria at 0.5 to 1.0 p.p.m., and to other bacteria at 1 p.p.m. concentrations.

Rudolfs, Manganelli, and Gellman (11) found that household detergents present in sewage in quantities approximating concentrations of soap do not interfere with the biological oxidation of sewage.

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VI. SUMMARY OF TOXIC EFFECTS ON ANAEROBIC AND AEROBIC TREATMENT DEVICES, AND ON FLORA AND FAUNA OF STREAMS

The literature survey indicates that the toxic effects of wastes on the oxidation and deaeration of streams and on the B.O.D. test are limited. Because the work reported upon the effect of toxic substances on digestion, trickling filters, activated sludge, and the flora and fauna of streams is rather extensive, an effort has been made to summarize the available material in tabular form (Table IV). It should be understood that the tabulated information is not intended to set specific limitations, but is a summary of findings which may be valuable as a guide for those encountering various types of wastes, or waste components.

Table IV contains only information

TABLE IV.—Toxic Effects of Wastes and Compounds on Anaerobic and Aerobic Treatment Devices, and Flora and Fauna of Streams, as Indicated by Retardation or Inhibition of Activities

Waste or Chemical	Digestion[1] (p.p.m.)	Act. Sludge (p.p.m.)	Trickling Filters (p.p.m.)	Flora and Fauna[2] (p.p.m.)
Acetic acid	—	—	—	125–150
Acetone	5,000	—	—	9,280
Alcohol, butyl	5,000	—	—	—
Alcohol, ethyl	5,000	—	—	18,400
Alcohol, iso-amyl	5,000	—	—	881
Alcohol, methyl	5,000	—	—	32,000
Aluminum sulfate[3]	5	—	—	136
Aluminum sulfate	1,000	—	—	—
Ammonium chloride	—	—	—	<134
Ammonium hydroxide	—	—	—	<8.75
Ammonium sulfate	1,000	—	—	<106
Analine	—	—	—	279
Arsenic, arsenious oxide	—	—	—	1.9–14
Arsenic, arsenate	4	—	—	<20
Arsenic, arsenite	—	—	—	5–9.1
Benzene	1,000	—	—	—
Benzoic acid	—	—	—	146
Boron[3]	—	1	1	—
Calcium acid phosphate	2,500[4]	—	—	—
Calcium chloride	—	—	—	1,332
Calcium hydroxide	2,500[4]	—	—	—
Calcium polysulfide	100–200	—	—	—
Calcium sulfate	1,000	—	—	—
Carbon tetrachloride	2,000	—	—	—
Carbide waste	—	—[5]	—[5]	—
Chromium[3]	1–5	3	3	—
Chromium, trivalent chromic	2,000	—	—	<6
Chromium, trivalent chromate	5,000	2	10	—
Chromium, hexavalent chromate	10,000	—	—	—
Chromium, pot. dichromate	—	—	—	<0.6
Chromium, sodium chromate	—	—	—	0.32
Chromium, sodium dichromate	—	—	—	0.31
Citric acid	—	—	—	120–143
Cobaltous chloride	—	—	—	<26
Copper (Cu)[3]	1–2.4	1	1	0.1
Copper, daily addition (Cu)	50	—	—	—
Copper, cuprous	1,000	—	—	—
Copper, cupric chloride	—	—	—	0.08
Copper sulfate	1,000	—	—	0.096
Copper plating	300	—[5]	—[5]	—
Crankcase oil	No effect	—[5]	—[5]	—
Cyanide (carb. and plating)	1,200	1–2	1–2	—
Cyanide (CN)[3]	2	2	2	—
Cyanide, HCN	—	1	2	—
Cyanide, potassium	—	—	—	5
Cyanide, sodium	30	—	—	<3.4
Cyanide, sodium thiocyanate	500	—	—	<11.3
Detergents	500	Foaming	—[6]	—
Dye waste	—	—[5]	—[5]	—
Dye waste, sulfite[3]	—	30,000	30,000	—
Dye waste, sulfur black	2,500	—[5]	—[5]	—
Dyes, acid	—	10,000	10,000	—
Dyes, basic	—	10,000	10,000	—
Ethylene dichloride	10	—	—	—

TABLE IV (Continued)

Waste or Chemical	Digestion[1] (p.p.m.)	Act. Sludge (p.p.m.)	Trickling Filters (p.p.m.)	Flora and Fauna[2] (p.p.m.)
Ethyl ether	No effect[7]	—	—	—
Fer-alum[3]	5	—	—	—
Fer-alum sulfate[3]	5	—	—	—
Ferric chloride[3]	5	—	—	130
Ferrous sulfate	1,000	—	—	<152
Iron[3]	—	5	5	—
Formaldehyde	—	—	360	—
Gasoline	2,000	—	—	—
Gas Liquor[3]	—	3,000–5,000	—[5]	—[5]
Hydrochloric acid	—	—	—	56–62
Hydrogen sulfide	—	—	—	1
Lead	—	0.1	0.1	0.01–1
Magnesium sulfate	1,000	—	—	—
Mercaptan, methyl	—	—	—	1–50
Nickel	500	1–3	1–3	—
Nitric acid	—	—	—	107
Paint waste	—	—[5]	—[5]	—
Phenol	—	—	—	94
Pickling liquor	—	—[5]	—[5]	—
Sodium aluminate	No effect	—	—	—
Sodium benzoate	—	—	—	<650
Sodium bicarbonate	—	—	—	2,350
Sodium bisulfate	—	—	—	190
Sodium bisulfide	—	—	—	<145
Sodium carbonate	—	—	—	300
Sodium chloride	50,000	—	—	<4,200
Sodium hydroxide	—	—	—	100–1,000
Sodium nitrate	No effect[8]	—	—	5,000
Sodium sulfate	1,000	—	—	5,000–7,100
Sodium sulfide	—	—	—	2–1,000
Sodium sulfite	—	—	—	300
Sodium thiosulfate	—	—	—	<520
Sulfite liquor[3]	—	10,000–60,000	10,000–60,000	—
Sulfuric acid	1,000	—	—	29–88
Tannery waste	No effect	—[5]	—	—
Tannic acid	—	—	—	<26
Textile waste (kier)	—	—[5]	—[5]	—
Toluene	1,000	—	—	—
Trinitro-toluene	60	—[5]	—[5]	—
Wool scouring waste	100,000	—	—	—
Xylene	1,000	—	—	—
Zinc[3]	20	—	—	—
Zinc—plating waste	600	—	—	—
Zinc sulfate	1,000	—	—	<48

[1] Unless otherwise specified, materials added to or present in sludge.
[2] Does not include fish.
[3] Materials present in sewage.
[4] Maximum amount studied.
[5] Interference.
[6] Affects loading on filters.
[7] 0.5 per cent was maximum amount studied.
[8] 2,500 p.p.m. was maximum concentration studied.

from results given in the literature in a more or less definite form. The number of references is materially greater than the number of compounds and wastes studied or reported. In many instances, a number of references pertain to the same wastes or compounds; in these cases, either the minimum toxic dosages have been recorded or, in some instances, ranges are given. For additional information, the review must be consulted; when detailed information is required the original papers should be used, because particular conditions frequently may modify the reported results.

Although a considerable amount of work has been done during the last 25 years, the tabulation vividly shows the lack of information for many substances, compounds, and industrial wastes. The general effects of acidity and alkalinity as indicated by pH values have not been recorded.

SELECTED BIBLIOGRAPHY OF LITERATURE ON FRUIT AND VEGETABLE PROCESSING WASTES

Intended as an aid to anyone wishing to learn of past and present conditions and practices with respect to food processing wastes, a selected bibliography on the subject is now available. It presents three groups of references covering, respectively, legal aspects, treatment and disposal, and utilization of fruit and vegetable processing wastes. The references were selected from the literature appearing in trade and technical periodicals during the years 1937 to 1948, inclusive. Also included is a list of recommended mimeographed information circulars published by the Bureau of Agriculture and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

Entitled "A Selected Bibliography of Periodical Literature on Fruit and Vegetable Processing Wastes," the 12-page mimeographed pamphlet was prepared by O. R. Vasak and W. L. Shaw, of the Bureau of Agricultural and Industrial Chemistry.

Copies of the bibliography, designated as "AIC-232," are available from the Bureau's Western Regional Research Laboratory at Albany, Calif., or from the U. S. Department of Agriculture, Washington, D. C.

DISPOSAL OF CYANIDES BY COMPLEXATION

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The safe disposal of waste cyanide solutions from electroplating systems has become a problem of increasing importance within the last few years. This is particularly true in the case of very dilute rinse waters, as the chemical methods for destruction of cyanide are not economical nor are they very efficient in other than concentrated solutions. Following the early attempts at destruction of cyanide by treatment with acid, conversion to ferric ferrocyanide, and oxidation with lime-sulfur mixtures or potassium permanganate, all of which were only useful with concentrated solutions, the development of the chlorination and hot electrolytic oxidation methods seemed to offer the best possibilities. These methods, however, are most effective where concentrated cyanides are to be treated. They have the further disadvantage of high cost. Some attention has been given to removal of cyanides by ion-exchange methods, but to date the resins available for this purpose do not appear to be satisfactory for industrial application.

It is proposed in this paper to review a possibility in the treatment of dilute cyanide waste solutions which, although it may not provide a complete answer to the problem in most cases, may be used in some locations to alleviate the pollution problem at a minimum of cost. This possibility lies in taking advantage of the ability of the cyanide ion to form very tightly bound complexes with certain metallic ions. By proper combination of the effluents from the majority of metal-plating operations it should be possible to produce an innocuous discharge at the plating plant.

Before discussing this process further, it would be profitable to review the chemistry of the cyanide complexes and the different solubility and equilibrium relationships to be derived from them.

Chemistry of Complex Formation

The metallic ions capable of forming complexes with cyanide include, among others, the ferrous, ferric, silver, cadmium, cuprous, mercuric, cobaltic, nickelous, and zinc ions. As an example of the sequence followed in the formation of these complexes, reference is made to the commonly known Liebig method for the estimation of cyanide by silver nitrate titration. In the unmodified titration a solution of silver ion is added to a solution containing free cyanide ion. Although silver cyanide is insoluble in water, and in fact has a solubility product constant of 2×10^{-12}, no precipitate is formed during the initial stages of the titration. This is due to the fact that an excess of free cyanide ion is present, in which the silver cyanide dissolves to form the complex $Ag(CN)_2^-$ ion:

$$2NaCN+AgNO_3\rightarrow NaAg(CN)_2+NaNO_3$$

When a quantity of silver ion has been added equivalent to that of the free cyanide, the first excess of silver ion will cause the precipitation of silver cyanide by reacting with the complex:

$$NaAg(CN)_2+AgNO_3\rightarrow \underline{Ag[Ag(CN)_2]}+NaNO_3$$

Free cyanide is always present until an equivalent amount of metal ion has been added. The appearance of the metal cyanide precipitate, however,

TABLE I.—Solubility of Metal Cyanide Precipitates in Water (1)

Precipitate	Sol. in Water (g./l.)	Temp. (°C.)
Silver cyanide	0.000028	18
Zinc cyanide	0.0058	18
Copper cyanide	0.014	20
Nickel cyanide	0.0592	18
Cadmium cyanide	17	15
Mercuric cyanide	93	14

gives visible assurance of the absence of free cyanide in the solution in any significant quantity. If an additional quantity of free cyanide is added to the mixture of metal cyanide complex and metal cyanide precipitate, some of the precipitate will then dissolve and react to form more of the complex:

$$2NaCN + Ag[Ag(CN)_2] \rightarrow 2NaAg(CN)_2$$

Equilibria in Complex Solutions

In a solution containing only the metal cyanide complex and precipitated metal cyanide, the concentration of free cyanide will depend on both the dissociation of the complex and the solubility of the precipitate. This concentration is expressed mathematically as a function of the solubility product constant, K_{SP}, of the precipitate and the dissociation constant (or "instability" constant), K_D, of the complex (Table II).

In considering these equilibria with regard to the cyanide disposal problem, one fact is immediately evident. As long as the cyanide ion can be kept bound up in a complex, the amount of free cyanide ion in the solution should be below the limits of toxicity as presently conceived. As long as the cyanide complex only is present, release of toxic free cyanide should be extremely slow, and will be controlled entirely by the rate of loss of free cyanide from the solution.

TABLE II.—Dissociation Constant, K_D, of Metal Cyanide Complexes at 25° C (2) (5)

Complex	Dissociation Constant
$Fe(CN)_6^{---}$	1×10^{-36}
$Ag(CN)_2^-$	1×10^{-21}
$Cd(CN)_4^{--}$	1.4×10^{-17}
$Cu(CN)_2^-$	5×10^{-28}
$Hg(CN)_4^{--}$	4×10^{-42}
$Ni(CN)_4^{--}$	1×10^{-22}
$Zn(CN)_4^{--}$	1.3×10^{-17}

This consideration invites a careful examination of the list of complex-forming metals in the hope that one of them might be particularly suited to the problem of disposal of waste cyanide. Silver, mercury, and cobalt may be ruled out immediately from the standpoint of either high cost or lack of general availability in the plating room. Cadmium, copper, and zinc may also be dismissed as possibilities where these salts are used in cyanide plating baths, as the prime requirement for the metal to be used lies in its availability as a metallic ion and not as a complex. This leaves the ferrous and ferric ions, and nickel, as possibilities in this system. Iron salts may be available in the rinse waters from pickling processes, but neutralization of the acid present would be necessary before using these rinses on cyanide waste waters. Neutralization would result in the formation of ferrous and ferric hydroxides and would immediately complicate the complexation process. It is possible to form the more desirable ferrocyanide complex by reacting ferrous hydroxide with a considerable excess of cyanide ion, but the generally unsatisfactory reaction conditions, plus the fact that not all of the cyanide can be bound up in a complex by this method, makes the method unsuitable as a simple disposal process.

This leaves the metal nickel as a possibility. Because plating solutions containing nickel are usually well buffered at neutral to slightly acid pH values, the difficulties inherent in the use of pickling rinses would be avoided. A closer examination of the possibility of using the nickel rinse as a treating and complexing agent for the cyanide

rinses seems warranted under these conditions.

In a solution containing only the nickelocyanide complex, the dissociation constant for the complex follows the mechanism of equilibrium—

$$Ni(CN)_4^{=} \leftrightharpoons Ni^{++} + 4CN^-$$

from which

$$K_D = \frac{[Ni^{++}][CN^-]^4}{[Ni(CN)_4^{=}]}$$

The precipitate of nickel cyanide, when immersed in a water solution, will dissolve to the extent of 0.0592 g. per l. (5.34×10^{-4} moles per l.), and the nickel cyanide in solution will ionize in either of two ways—

$$Ni(CN)_2 \rightleftarrows Ni^{++} + 2CN^-$$

or

$$Ni[Ni(CN)_4] \leftrightharpoons Ni^{++} + [Ni(CN)_4]^=$$

In a solution containing only the nickel cyanide complex and in contact with solid nickel cyanide, the concentration of free cyanide will be dependent on the relationship of the two equilibria expressed above—that of dissociation of the complex ion, and that of ionization of the nickel cyanide in solution.

If the first system of ionization is selected, the following relationships will exist:

$$K_D = \frac{[Ni^{++}][CN^-]^4}{[Ni(CN)_4^{=}]}$$

and

$$K_{SP} = [Ni^{++}][CN^-]^2$$

Therefore,

$$\frac{K_{SP}}{[CN^-]^2} = \frac{K_D[Ni(CN)_4^{=}]}{[CN^-]^4}$$

and

$$[CN^-] = \sqrt{\frac{K_D[Ni(CN)_4^{=}]}{K_{SP}}} = \sqrt{\frac{K_D}{K_{SP}}[Ni(CN)_4^{=}]}$$

If, as would be more reasonable on the basis of existing evidence, the second system of ionization is selected, the following relationships will be found:

$$K_{SP} = [Ni^{++}][Ni(CN)_4^{=}] = 7.2 \times 10^{-8}$$

and

$$[Ni^{++}] = \frac{K_{SP}}{[Ni(CN)_4^{=}]}$$

Therefore,

$$\frac{K_{SP}}{[Ni(CN)_4^{=}]} = \frac{K_D[Ni(CN)_4^{=}]}{[CN^-]^4}$$

and

$$[CN^-] = \sqrt[4]{\frac{K_D}{K_{SP}}[Ni(CN)_4^{=}]^2} = 1.94 \times 10^{-4}\sqrt{[Ni(CN)_4^{=}]}$$

From this expression may be calculated the theoretical concentration of free cyanide ion present in a water system containing the nickel cyanide complex and solid nickel cyanide. Figure 1 illustrates the concentrations of free cyanide possible with varying initial quantities of cyanide which have been transformed to the nickel cyanide complex. It should be noted that as much as 80 p.p.m. of cyanide can be present in the complex form before the free cyanide from dissociation of the complex exceeds 0.15 p.p.m.

Where a nickel cyanide complex has been formed by reaction of a slight excess of nickel salt with a dilute cyanide waste solution, and the resulting precipitate of nickel cyanide removed by sedimentation or other means, the concentration of free cyanide ion in the effluent solution will be controlled mainly by the dissociation or instability constant of the complex ion. Because no nickel or complex ions are available from solution and ionization of solid nickel cyanide, the solubility product constant of the solid cyanide will no longer affect the equilibrium. In this case, the concentration of free cyanide will be entirely dependent on the dissociation of the complex ion

$$Ni(CN)_4^{=} \leftrightharpoons Ni^{++} + 4CN^-$$

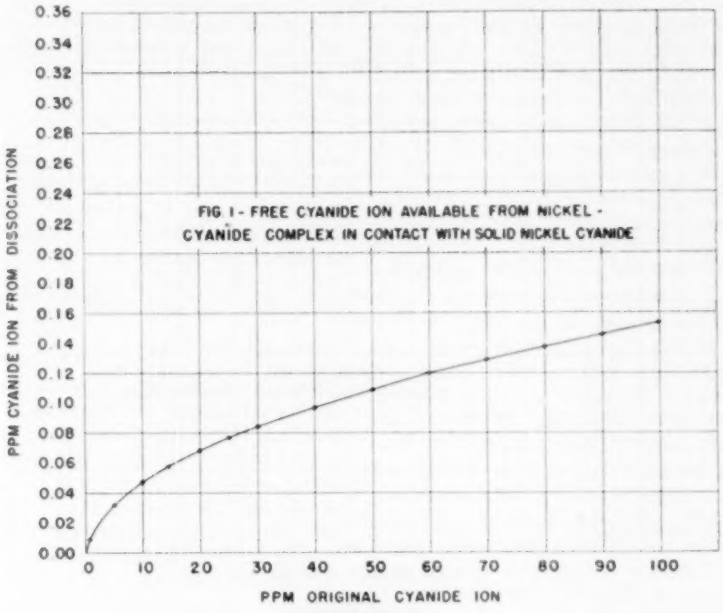

FIGURE 1.

and the theoretical concentration of free cyanide may be calculated by conventional methods:

$$\text{let } x = [Ni^{++}]$$
$$\text{then } 4x = [CN^-]$$
$$\frac{[Ni^{++}][CN^-]^4}{[Ni(CN)_4^{=}]} = K_D = \frac{x(4x)^4}{[Ni(CN)_4^{=}]} = 1\times10^{-22}$$
$$x = \sqrt[5]{\frac{1\times10^{-22}}{256}[Ni(CN)_4^{=}]}$$
$$[Ni^{++}] = 1.31\times10^{-5}\sqrt[5]{[Ni(CN)_4^{=}]}$$
$$[CN^-] = 5.24\times10^{-5}\sqrt[5]{[Ni(CN)_4^{=}]}$$

The concentrations of free cyanide available by this mechanism are given in Figure 2.

Maintenance of either of the above conditions can result, therefore, in the production of an effluent solution which should not be toxic to fish life (3). The information developed above is based on the assumption that only the cyanide ion and the nickel ion are present and that they are in solution in distilled water. Obviously, in plating room practice the effluent from the various rinse tanks will be considerably more complex in composition. The cyanide rinse being discharged may contain some metallic complex, such as copper, zinc, or cadmium cyanide, accompanied by excess sodium cyanide, sodium hydroxide, sodium carbonate, Rochelle salt, brighteners, etc. In addition, the nickel rinse will also contain such materials as ammonium chloride, boric acid, sulfates, brighteners, and wetting agents, depending on the type of plating being done. Depending on the geographic location of the plant, the composition of the water itself will affect the equilibria developed among the various ions. Accordingly, some consideration should be given to the actual mechanism of this complexation process in the presence of the heavy metal cyanides.

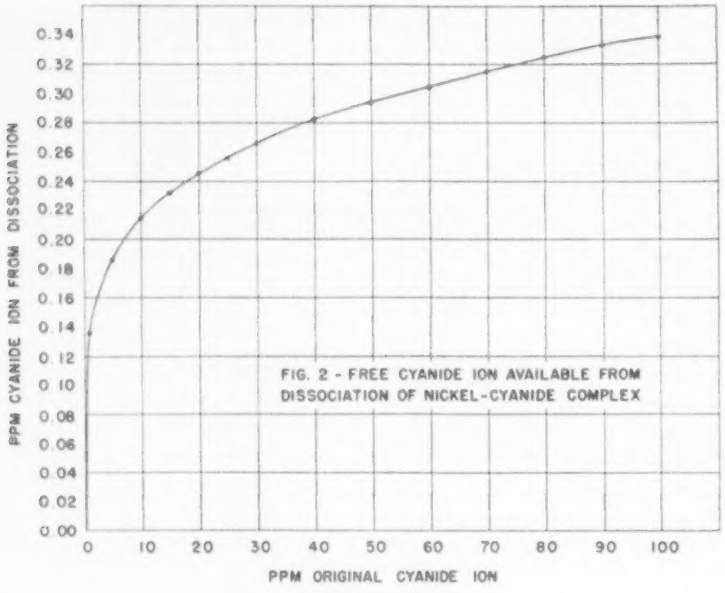

FIGURE 2.

An excess of free cyanide is present in the rinse solutions from copper, zinc, or cadmium plating; therefore, the metals exist in the form of cyanide complexes. When a nickel salt is added to this mixture, the formation of the nickelocyanide complex will decrease concentration of free cyanide until no more is present. At this point, the question arises as to whether addition of nickel ion will result in the formation of nickel cyanide precipitate or whether the nickel will replace the other heavy metal in its cyanide complex. Replacement of the heavy metal in the cyanide complex will depend, of course, on the relative magnitude of the dissociation or instability constant for the complex in question. If the dissociation constant for the complex heavy metal involved is smaller numerically than the dissociation constant for the nickelocyanide complex, then no replacement of metal will take place. If, on the other hand, the dissociation constant for the heavy metal complex is larger numerically than the dissociation constant for the nickelocyanide complex, then the metal will be displaced from its complex and will, in the usual natural water, precipitate as either the hydroxide, the carbonate, or the basic carbonate. Reference to the table of dissociation complexes will establish the order of stability to the nickel ion for the metals involved in most plating systems. For the purposes of this discussion, however, it is obvious that elimination of free cyanide in the solution will be accompanied by the formation of a precipitate. Whether the precipitate is nickel cyanide or the hydroxide, carbonate, or basic carbonate of the heavy metals makes little difference. If this complexation process is carried out in a sludge bed precipitator type of equipment, the insoluble heavy metal precipitate will act as a safeguard against the passage of occasional small excesses of free cyanide. The precipitates formed by the reactions indicated above, when

placed in contact with free cyanide, will each dissolve to form the respective cyanide complex.

Application

In the process, therefore, the rinse water from the nickel plating solution will be conducted to the rinse water from the cyanide operation and mixed thoroughly. To insure the presence of an excess of nickel ion for the formation of the complex, the ratio $\frac{\text{p.p.m.Ni}^{++}}{\text{p.p.m.CN}^{-}} > 0.56$ must be maintained in the solution at the moment of mixing. Use of a ratio of 0.6 parts of nickel ion to one part cyanide ion would probably represent an adequate safety factor. It should be noted that the formation of a precipitate is essential at this stage to insure complete reaction of the free cyanide. The mixture will be allowed to enter a reaction chamber and the precipitate allowed to settle. Operating on a continuous-flow basis, it would be advisable for the reacting waters to enter below the slurry bed, using the sludge bed filtering technique to guarantee both saturation with nickel cyanide and complete filtration. The effluent from the process will then be permitted to flow freely to the sewer or watercourse. As the effluent is no longer in contact with the solid nickel cyanide precipitate, the concentration of free cyanide in this solution will be governed by the extent of dissociation of the complex ion, and modified by whatever influence may be exerted by the presence of the other constituents of the waste.

Discussion

In making use of the dilution principle in discharging waste liquids to a nearby stream, the industrial waste engineer frequently finds that thorough mixing presents the most difficult problem. Unless rather elaborate precautions are taken, the discharged liquid often shows a discouraging tendency to flow in a concentrated stream from the point of discharge until some interference with stream flow causes turbulence and mixing. In these cases the concentration of toxic materials in the effluent must be severely restricted, due to the damage done to aquatic life in the path of the discharge. Where the toxic effect of an element is neutralized, however, these restrictions on concentration may be relaxed and full advantage taken of the eventual dilution possibilities of the stream.

In the case of the disposal of a cyanide complex, this theory would also hold true. The complex itself is relatively nontoxic to aquatic life, as compared with the free cyanide ion, and could be disposed of at a much higher concentration. [In an examination of the toxic effect of the nickelocyanide complex, common goldfish weighing approximately 1½ g. each were exposed to a solution prepared by adding nickel sulfate to a solution of sodium cyanide. At the end of 24 hr. these fish showed no difference in behavior from similar fish used as controls. Analysis of the solution indicated the presence of less than 3 p.p.m. CN (Liebig method), 104 p.p.m. CN by distillation, and 77 p.p.m. nickel; the pH value was 8.1.] Eventual dilution by the stream would serve not only to diminish concentration by the dilution process alone, but also would encourage slow release of free cyanide ion in infinitesimal and nontoxic amounts. The greater proportion of this free cyanide would be converted immediately to hydrocyanic acid under the conditions prevailing in most streams (4). Loss of this hydrocyanic acid, either by hydrolysis to nitrogen compounds, oxidation to cyanates, or by operation of Henry's law, would result in the eventual disappearance of the original cyanide complex. Unless some drastic change occurred in the quality of the receiving water, this loss of cyanide would proceed in such a manner that no toxic concentration would be present at any time.

Certain objectionable characteristics

of the less strongly bound cyanide complexes should be noted at this point with respect to their use in the manner previously described. In the first place, although the nickelocyanide complex is considered a stable complex, it may be decomposed by strong acids with the formation of free hydrocyanic acid. This results from the fact that the nickelocyanic acid formed is a very weak acid and is unstable. Thus,

$$Na_2[Ni(CN)_4]+2HCl\rightarrow H_2[Ni(CN)_4]+2NaCl$$
$$H_2[Ni(CN)_4]\rightleftarrows 2HCN+Ni(CN)_2$$

The possibility of exposure to extremely acid river waters would have to be determined in considering this method. As most streams are alkaline in character, however, and possess considerable capacity for neutralizing acids discharged to them, and as it is very doubtful that the pH value of a stream could be lowered enough to produce such an effect, little concern need be felt over this possibility. The problem of destruction of the nickelocyanide complex in water courses by the inadvertent discharge of a waste acid will be dependent almost entirely on the natural alkalinity of the water. The higher the bicarbonate alkalinity, the more acid will be necessary to achieve that level of low pH value at which the nickelocyanide complex is destroyed. Therefore, any consideration of the use of this complexation procedure might profitably take into account the chemical nature and size of the watercourse to which it is eventually discharged.

A second objection to the presence of the nickelocyanide complex in a water supply lies in the possibility of its decomposition by chlorine to cyanogen chloride in alkaline solutions, as follows:

$$2Na_2[Ni(CN)_4]+6NaOH+9Cl_2\rightarrow 2Ni(OH)_3+8CNCl+10NaCl$$

It is probable, however, that in a normally alkaline natural water this reaction will not produce cyanogen chloride, but that the cyanide will be converted instead to a cyanate according to the reaction

$$CNCl+2NaOH\rightarrow NaOCN+NaCl+H_2O$$

In any case, the possibility of formation of significant amounts of cyanogen chloride at the point of reaction with chlorine should be considered in estimating the effect of this complexation on downstream installations.

Discharge of a nickelocyanide complex to a sewage system can probably be accomplished with very little difficulty. It is sometimes noted among sewage plant operators in systems serving a large industrial city that although it is certain that large quantities of cyanide are disposed of to the sewer system daily, no evidence of free cyanide can be found in the sewage at the treatment plant. This suggests that during its progress from the industry to the sewage treatment plant the free cyanide is either adsorbed by certain components of the sewage or is removed from solution in the form of an organocyanide complex.

Use of deliberate complexation as a method for treatment of dilute cyanide wastes may make modification of present stream standards advisable. Most of the present standards limit the quantity of pollutant in the stream or waste discharge by such wording as "not to exceed one part of cyanide as CN to one million parts of water. . . ." If complexation is accepted as a satisfactory means of treatment, then this stipulation should be revised to read "not to exceed one part of *free* cyanide as CN to one million parts of water. . . ."

Application of this procedure to the plating plant may conceivably take the form of introducing the nickel rinse overflow to the rinse tank following cyanide plating. By use of this procedure, either as a cascade system or by repumping, it may be unnecessary to set up additional treatment installations outside the plating tanks. Ordinarily the rinse waters flowing from the

nickel plating system are fairly high in nickel concentration and will usually contain enough nickel to insure complete complexation of the cyanide rinses produced in the average copper-nickel-chrome plating plant. Each plant, however, will present its individual problem, and a thorough survey of the rinse wastes by a competent chemist or chemical engineer should always precede action of this nature.

Summary

The possibility of safe disposal of cyanide rinse waters by combining with nickel-bearing rinses to form the tightly bound nickelocyanide complex is presented. The theory of complex-forming reactions is outlined, and the equilibria existing during operation of the treatment process are discussed. By calculations based on these equilibria, it is pointed out that where the nickelocyanide complex is formed, concentration of free cyanide is maintained below the toxic range.

The complexation procedure for cyanide rinse waters will provide the electroplater with a treatment method at no cost for additional chemical agents. The essential ingredients are commonly being wasted from most electroplating plants and require only the proper sequence of mixing to produce the desired results. With this method available, no electroplater need plead high cost as an excuse for non-treatment of waste cyanide.

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NUTRITIONAL REQUIREMENTS IN THE BIOLOGICAL STABILIZATION OF INDUSTRIAL WASTES

I. EXPERIMENTAL METHOD *

By E. N. Helmers, E. J. Anderson, H. D. Kilgore, Jr., L. W. Weinberger, and C. N. Sawyer

Biological treatment utilizing either trickling filters or activated sludge is well established as an effective method for stabilizing domestic sewage and certain industrial wastes; however, serious difficulties have been encountered in the biological treatment of many trade wastes. Activated sludge has proved especially sensitive to industrial waste loadings, as indicated by bulking and rising sludge and unsatisfactory rates of B.O.D. removal. Also, biological filters are not immune to poor efficiencies, ponding, and other ills.

Such failures of biological treatment processes may be caused by a variety of circumstances, many of which can be attributed to properties of the waste. Excessive loadings, toxic substances, or deficiencies in certain nutritional elements essential for the normal functioning of biological life, are all factors any one of which can result in the failure of biological treatment. The purpose of the laboratory studies with which this and subsequent papers are concerned was to evaluate the importance of the nutritional factor.

History and Previous Work

Some of the first work showing the importance of nutrient elements in the bacterial stabilization of an organic substrate was the result of research on the B.O.D. test. In 1931, Butterfield, Purdy, and Theriault (1) concluded from experimental observations that biochemical oxidation is effected only by growing cells. A few years later, Lea and Nichols (2)(3) elaborated on this theory when they concluded from experimental findings that the maximum B.O.D. of a waste can be obtained only when sufficient cell building materials are present in the substrate.

In 1940, Sawyer (4)(5) applied these ideas of nutrition to the activated sludge process. Laboratory stabilization of waste sulfite liquor-sewage mixtures by activated sludge indicated that the rate of B.O.D. removal was a function of the amount of available nitrogen. Recent work (6) has extended the study of nitrogen and phosphorus nutrition to the stabilization of pure substances and waste-sewage mixtures by activated sludge. An extensive study of the nitrogen metabolism of activated sludge has recently been made by Weinberger (7).

Objectives and Scope of Work

The primary objective of this research has been the determination of nitrogen and phosphorus requirements of both activated sludge and biological filters in the stabilization of several industrial wastes. Also, an attempt was made to evaluate the quantitative effects of variations in the availability of nitrogen and phosphorus on these biological treatment processes.

Two conditions of treatment were recognized and experimental procedures adopted for the study of both:

* Contribution from the Sedgwick Memorial Laboratories, Mass. Inst. of Tech., Cambridge, Mass.

1. The treatment of industrial waste and domestic sewage in mixtures, such as might be encountered in a municipal treatment plant. Under these circumstances, most of the nutritional elements are supplied by the sewage; the question is, what quantities of waste can be tolerated in the mixture being treated?

2. The treatment of industrial wastes without the benefit of admixture with sewage, as in the case of a private industrial waste treatment plant. Because only a fraction of the required nutritional elements may be available under these conditions, supplementary nutritional elements were added in varying amounts in order to determine the critical amounts of nitrogen and phosphorus required for rapid, satisfactory treatment.

Experiments were conducted at constant temperatures of 10°, 20°, and 30° C. to correspond to winter, spring and fall, and summer operating conditions.

Selection of Industrial Wastes

The industrial wastes used for these studies were selected because of nutritional deficiencies in either nitrogen or phosphorus, or both. The particular wastes studied were:

1. Cotton kiering waste—an alkaline waste, deficient in nitrogen, from the deterging of cotton gray goods.

2. Rag-rope pulping waste—a highly concentrated and alkaline cooking liquor deficient in both nitrogen and phosphorus.

3. Brewery waste—primarily waste wort deficient in nitrogen and phosphorus.

4. Tannery waste—from the manufacture of side leather and sheepskin with chrome tan; contains an excess of nitrogen, but is deficient in phosphorus.

This paper considers experimental and analytical methods employed; future papers in the series will treat the detailed results of experiments involving the previously listed wastes.

Experimental Method—Activated Sludge

Apparatus

The apparatus used in the activated sludge studies is shown in Figure 1.

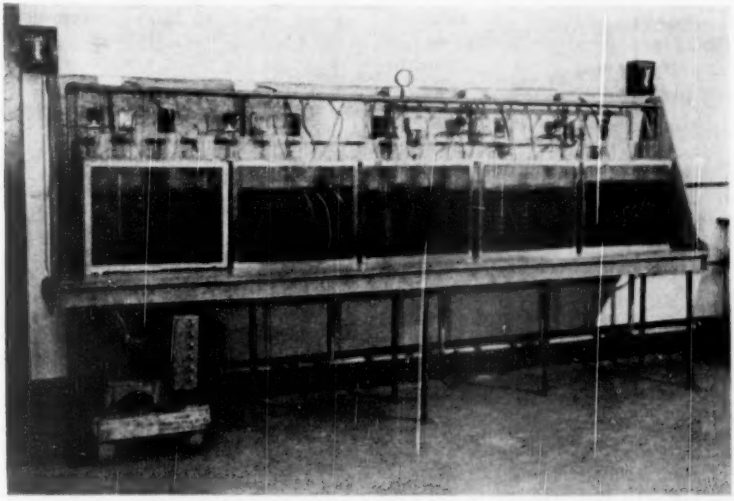

FIGURE 1.—Apparatus used in activated sludge studies.

The equipment consisted of five constant temperature (± 0.5° C.) water baths, each bath containing four 2½-l. Pyrex glass tubes. Air was supplied to the bottom of each tube through a carborundum diffuser.

Feeding Procedure

In preparation for a run, the first step was to develop activated sludge in the aeration tubes by feeding different mixtures of waste and sewage, or by feeding a constant waste load supplemented with varying amounts of nutrients. When the concentration of aeration solids reached 1,500 p.p.m. in the mixed liquor for each tube, controlled feeding was begun.

Feedings were conducted three times each day at 8-hr. intervals. At the appointed time, the air line was withdrawn and the sludge allowed to settle for approximately ½ hr. Sufficient supernatant was then poured off to leave 0.5 l. in each tube. Finally, each tube was fed 1 l. of the required feed mixture to bring the volume of mixed liquor up to 1½ l., and the air line returned.

The amount of air supply was adjusted to be in substantial excess of that usually provided in activated sludge plant aeration tanks, so that the air supply would not be a limiting factor in any of the experiments.

Analytical Control

The pH of all the industrial wastes was adjusted in the range of 7 to 8 before mixing with sewage or feeding to the activated sludge. A record was kept of pH conditions in the aeration mixtures.

Samples of mixed liquor were taken for suspended solids analysis once each day. By drawing off a portion of the mixed liquor from each tube before each feeding, the amount of aeration solids was kept as close as possible to 1,500 p.p.m. An accurate record of sludge growth was maintained for each tube throughout the course of a run by keeping a record of the amount of mixed liquor drawn off.

After the commencement of controlled feedings, several days were allowed for acclimatization, as indicated by a consistent rate of sludge growth and effluent analysis, before the run proper was started. Acclimatization is deemed to be of utmost importance if reproducible results are to be obtained.

Three-day composite samples of the effluents were taken for analysis throughout each run. Composites preserved in chloroform were analyzed for nitrite and nitrate nitrogen, and total and soluble phosphorus; composites preserved in sulfuric acid were analyzed for organic and ammonia nitrogen. The 5-day, 20° C., B.O.D. of all effluents was also determined on freshly collected samples several times during the course of a run. An average run, throughout which feeding conditions were maintained constant, was continued long enough to give 5 or 6 composite samples.

At the conclusion of the last composite sample of a run, data were obtained for sludge settling curves. Finally, the remaining sludge was filtered, dried at 103° C., and analyzed for nitrogen, phosphorus, and volatile matter.

Experimental Method—Trickling Filter

Apparatus

The apparatus used in the trickling filter studies is shown in Figure 2. Two 2-stage high-rate filters were operated in parallel at room temperature, which averaged about 28° C. The primary and secondary filters were each 4 in. in diameter and 3 ft. deep, and contained 1.5- to 2.5-in. rock. Intermediate and final settling were provided in circular stainless steel clarifiers. Final effluent was recirculated in desired amounts to the primary dosing siphon. The feed mixture and

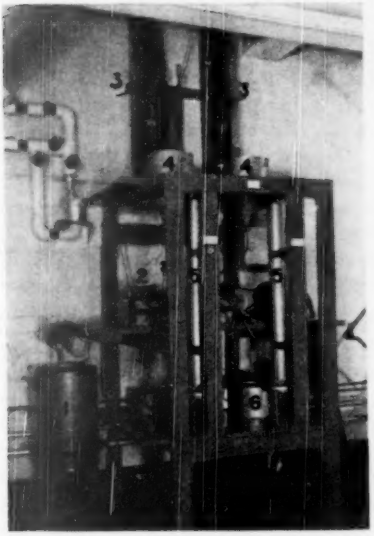

FIGURE 2.—Experimental high-rate trickling filters, showing: (1) feed tank, (2) feed and recirculation pump, (3) primary filters, (4) intermediate clarifiers, (5) secondary filters, and (6) final clarifiers.

recirculated effluent were pumped by a rotary positive displacement pump.

Feeding Procedure

The feed mixture under investigation, either domestic sewage plus industrial waste or industrial waste supplemented with nitrogen and phosphorus, was freshly prepared every 8 or 12 hr. and added to the feed supply tanks. A slow-speed stirrer kept suspended solids of the feed mixture in suspension. The feed was applied at rates of 5 to 10 m.g.a.d., with sufficient recirculation of settled filter effluent to give application rates of 20 or more m.g.a.d. B.O.D. loadings varied from 2,200 to 5,000 lb. per acre-ft. per day.

Analytical Control

Accumulations of filter growths were not normally removed from the stones between individual runs but, rather, a lengthy acclimitization period was allowed before starting each new series of composites. When effluent analysis showed consistent results for several days the filter was considered to be stabilized, and data were collected for comparative purposes. Composite samples of the feed, intermediate clarifier effluents, and final clarifier effluents were collected and analyzed in the same manner as they were for the activated sludge experiments.

Analytical Methods

In general, the chemical and physical analyses of the composite effluent samples and dried activated sludge were made in accordance with Standard Methods (8).

Ammonia nitrogen was determined by the distillation of a neutralized sample to which phosphate buffer had been added; the distillate was absorbed in a saturated boric acid solution and titrated with standardized sulfuric acid to the methyl orange end point. The still bottom liquor was used for the organic nitrogen determination, in which a copper selenite catalyst was employed in place of potassium or sodium sulfate (9) (10).

Nitrite and nitrate nitrogen, and soluble and total phosphorus, were determined colorimetrically using a Coleman spectrophotometer. Nitrite nitrogen was found by the Rider and Mellon modification (11) of the sulfanilic acid method. Nitrate nitrogen was found by the phenol-disulfonic acid method and a correction made for interference caused by chloride ion (12). This nitrate test was not very satisfactory; when nitrate was present in appreciable quantities the results of the determinations are of doubtful accuracy.

Phosphorus was determined using molybdic acid, to which 1 per cent sulfamic acid was added to eliminate nitrite interference (13). Total phosphorus for the sludges was found by igniting a known weight of oven dried

sludge, dissolving the residue in molybdate solution, and applying the stannous chloride method.

Aeration solids concentrations were determined by employing a slight modification of the aluminum dish method.

Analysis of Data—Activated Sludge

The analysis of data obtained from the activated sludge runs was based on certain definitions and theories concerning the mechanism of the treatment process. The "nitrogen (or phosphorus) requirement" is defined as the amount of nitrogen (or phosphorus) utilized by the activated sludge in the stabilization of a substrate. The "maximum requirement" is the amount utilized when an excess of the nutrient is available in the feed mixture, and the "critical requirement" is defined as the amount of nutrient which must be available for satisfactory treatment plant operation. Of course, the term "satisfactory treatment" must be defined for individual plant conditions in order to determine critical requirements.

The term "available nitrogen" (or phosphorus) is used to represent that portion of the nutrient under consideration which is in a chemical and physical form that can be assimilated by activated sludge; that is, growing organisms. Thus, a nutrient "excess" or "deficiency" depends on whether or not the waste mixture contains available nutrients in large enough quantities to satisfy maximum requirements of the sludge.

Nutritional requirements were calculated using a theoretical balance equation based on the assumptions of treatment process equilibrium and no net gain or loss of nutrients as a gas. In other words, the amount of nutritional element coming out of the process must be equal to the amount of nutritional element put in, or

$$I = E + \frac{Gn}{200} \qquad (1)$$

in which

I is the p.p.m. of nutrient element in the influent feed mixture,

E is the p.p.m. of nutrient element in the effluent,

G is the p.p.m. per day rate of sludge growth, and

n is the percentage of nutrient element in the dry sludge (N used for percentage of nitrogen, P for percentage of phosphorus).

As written, the constants of Eq. 1 apply to the experimental conditions of three feedings per day and a 2:1 ratio of influent feed mixture to return sludge.

The term $Gn/200$, or equivalently $I - E$, represents the nutritional requirement of the activated sludge. Because the nutritional requirement can be expressed in two ways, it can be calculated from the growth and sludge analysis data or from the analyses of feed mixture and effluent. Both methods are used, and the inherent check of the calculation is one of its most important features.

An example of the data needed for calculation of a nitrogen balance and a sample "balance" calculation are shown in Table I, from which it will be seen that values obtained for $GN/200$ and $I_n - E_n$ are in reasonably good agreement—6.7 *vs.* 8.4 for Tube 1, and

TABLE I.—Calculation of Nitrogen Balance

Factor[1]	Tube[2]	
	1	3
I_n (p.p.m.)	26.1	33.3
E_n (p.p.m.)	17.7	12.9
G (p.p.m./day)	198	440
N (%)	6.78	8.38
$GN/200$ (p.p.m.)	6.7	18.5
$I_n - E_n$ (p.p.m.)	8.4	20.4

[1] Subscript n denotes that nitrogen is the nutrient element considered.

[2] Feed mixtures: Tube 1 (control), 100 per cent sewage; Tube 3, 90 per cent sewage plus 10 per cent waste.

TABLE II.—Comparison of Methods of Calculating Nutrient Requirements of an Industrial Waste when Treated in Combination with Domestic Sewage

Factor	Basis of Calculation			
	Sludge Growth		$I_n - E_n$	
	Tube 1	Tube 3	Tube 1	Tube 3
Total N required (p.p.m.)[1]	6.7	18.5	8.4	20.4
N required by sludge growth due to sewage (p.p.m.)[2]	—	6.0	—	7.6
N required by sludge growth due to waste (p.p.m.)[3]	—	12.5	—	12.8
B.O.D. reduction of waste (p.p.m.)	—	224	—	224
B.O.D./N ratio	—	17.9	—	17.5
N required (lb./100 lb. B.O.D. removed)	—	5.6	—	5.7

[1] From Table I.
[2] 90 per cent of control tube nitrogen requirement.
[3] Tube 3 requirement minus 90 per cent of control tube nitrogen requirement.

18.5 *vs.* 20.4 for Tube 3. The discrepancy is due, undoubtedly, to inherent errors in the methods of analyses and to small losses of nitrogen and sludge resulting in increased $I_n - E_n$ values and decreased $GN/200$ values.

In calculating the amount of nutrient material actually required by the waste fraction in a waste-sewage mixture, deductions must be made for the nutrient requirement of the sewage fraction, based on the data obtained in the control tube. Calculations of nitrogen requirements by the two methods are given in Table II. Phosphorus requirements were computed in a similar manner.

After nutritional requirements were determined, process variables—such as rate of B.O.D. removal, effluent B.O.D., sludge volume index, and other sludge characteristics—were compared with the available nitrogen and phosphorus in order to determine the quantitative effects of deficiencies on process efficiency. By establishing criteria of satisfactory treatment—criteria which will vary from plant to plant—critical nutritional requirements can be estimated.

Analysis of Data—Trickling Filter

The two trickling filters normally were operated in parallel. The same feed mixture was applied to both filters, but with different rates of B.O.D. loading or different recirculation rates. As there was no control filter to correspond to the control tube of the activated sludge experiments, nutritional requirements could be calculated only for the mixture as fed and not for the waste fraction alone. This calculation was made by subtracting the amount of nutrient in the effluent from that in the influent and relating the difference to the B.O.D. removed. The results were then compared with those obtained in activated sludge treatment of similar mixtures under comparable temperature conditions.

Summary

A consideration of nutrition is believed to be of importance in the design and operation of biological treatment plants for the stabilization of industrial wastes or industrial waste-sewage mixtures. A program of research has been designed to determine the nutritional requirements of activated sludge and trickling filters in the stabilization of several industrial wastes and to correlate nutritional supply with process efficiencies. The

apparatus and experimental method used in these studies have been described. Results concerning specific industrial wastes will be considered in future papers.

Acknowledgment

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FLY ASH DISPOSAL *

By H. L. Jacobs

Engineering Department, E. I. du Pont de Nemours and Co., Wilmington, Del.

Public interest in abatement of air pollution has become aroused much more quickly than was the case with stream pollution abatement. The Donora, Pa., disaster in October, 1948, undoubtedly accelerated the activity and aroused public concern in this field. In so far as fly ash is concerned, the problem frequently confronts the waste disposal engineer as a water pollution problem.

Magnitude of Problem

The quantity of fly ash collected in 1948 from approximately 65 per cent of public utilities producing coal-generated energy was 2,241,547 tons (1). This indicates that the total quantity of fly ash from public utilities alone would be in excess of 3,000,000 tons per year for the entire country. The average cost of disposal of this material in those cases where it is not sold runs about 66¢ per ton, or close to $2,000,000 per year. The total quantity of fly ash sold during 1948 was 151,447 tons, or about 5 per cent of the total produced. The average sale price for this material was 90¢ per ton.

Privately owned utilities have at present an investment of $30,000,000 in fly ash collecting equipment and this figure is expected to double in the near future.

Fly ash comes mainly from the use of pulverized coal. It differs from cinders in that particle sizes are small enough so that the ash particles are carried with the gas stream through and out the stack. The problem arises from the fact that atmospheric eddies carry these particles to the ground, where they impinge on surfaces or create clouds of dirty air, from which the ash is filtered by curtains, window screens, and laundry.

The increase in the use of pulverized coal has been at a more rapid rate than that for other types of installations. From 1920 to 1948 the coal consumed by utilities increased by about 3½ times. During the same period, however, the use of pulverized fuel increased approximately 33 times. The ratio of pulverized fuel to total coal consumed by utilities increased from 6 per cent in 1920 to about 60 per cent in 1948.

Fly ash weighs approximately 30 lb. per cu. ft. For each 50 tons of coal burned as pulverized fuel, approximately 4.5 tons pass through the stack as fly ash, assuming 10 per cent ash in the coal. If collectors are used, 3.8 tons per day of this material will be sluiced to the ash pond, along with 0.6 tons of cinders. For each carload of coal used per day, the storage area for fly ash amounts to about 2.1 acre-ft. per year. This does not sound like a large area until it is considered that some utilities burn many carloads of coal per day. A pulverized coal-burning plant rated at 1,000,000 lb. of steam per hour collects about 1 ft. per yr. of fly ash in a 60-acre settling pond.

Composition of Fly Ash

Fly ash usually contains some of each of the following: carbon, iron, calcium, magnesium, aluminum, silica, sulfur, titanium, and phosphorus. These constituents vary widely, with carbon

* Presented at 1950 Annual Meeting, Virginia Industrial Wastes and Sewage Works Assn.; Winchester, Va.; Mar. 30–31, 1950.

ranging from less than 1 per cent to more than 60 per cent by weight. In general, the carbon in fly ash from public utilities is less than from the average industrial powerhouse, because the former design for lower heat releases and do not overload their equipment so much. The particle size distribution depends on the manner in which the fuel is burned. With ordinary stokers and with spreader stokers, 20 to 40 per cent of the ash falls below 10 microns in size, whereas 80 to 90 per cent is less than 200 microns. With a pulverized fuel installation, 30 to 50 per cent of the particles are smaller than 10 microns, and about 90 per cent are less than 80 microns in size. With stokers, the quantity of fly ash reaching the stack is 25 to 50 per cent of the total ash, although in the case of the pulverized coal 80 to 90 per cent may reach the stack.

Why Fly Ash Is Collected

There are only two reasons for the installation of dust collectors—maintenance of good public relations and the existence of ordinances requiring it. One can see that both reasons stem from the same root—the public demand for clean air. For this single reason, the time will doubtless come when most powerhouses will operate within limits of fly ash emission established by law.

Standards

Many air pollution abatement ordinances are based on suggestions of A.S.M.E.; namely, that the solids concentration in the flue gases be limited to the equivalent of 0.25 grains per cu. ft. at 500° F. and 50 per cent excess air, but with a top limit of 85 per cent efficiency. A somewhat different emission rate is now being considered by A.S.M.E., based on

$$Y^2 = 600\,X$$

in which Y is the pounds of dust per hour, and X is the thousands of pounds of steam per hour.

Based on 10 per cent ash in the coal, 80 per cent of the ash going to the collector, and an evaporation rate of 10 lb. of steam per lb. of coal, the following efficiencies would be required for various loads:

200,000 lb. steam per hour = 78%
400,000 lb. steam per hour = 84.5%
800,000 lb. steam per hour = 89.3%

It can readily be seen that fly ash emissions based on such a formula would limit the size of boiler installation which could be installed. There is considerable feeling that other factors should be taken into consideration before standards are finally established.

Equipment for Fly Ash Collection

The methods which can be used are based on the principles of centrifugal force, electrostatic attraction, and straining or filtering. The latter method, embodying the bag filter, is applicable only where temperature and corrosion conditions are not severe. Powerhouse stack gases are not within that category. Where the proper conditions can be met, however, bag filters may remove dust particles in the sub-micron range. Multitube cyclones usually remove all fly ash larger than 20 microns and, of course, remove a substantial fraction of smaller particles. Pressure losses are in the range of 2 to 3 in. of water.

Venturi scrubbers followed by cyclones are efficient in the removal of sub-micron particles, but the power requirements are high because of the high pressure drops involved. There are some indications, however, that such a scrubber will give 95 per cent efficiency of removal of particles between 10 and 100 microns at a pressure drop of 5 to 6 in. of water.

Electrostatic precipitators are generally conceded to be the most efficient of the practical separators, although

results have been disappointing in some cases. The characteristics of the ash have been blamed in these cases. At one plant, in Pittsburgh, collection efficiencies at the same steam rate were 95.2, 89.4, and 87.5 per cent with three different coals. In general, however, electrostatic precipitators are expected to collect about 95 per cent of the ash.

The physical characteristics of the fly ash are bound to affect equipment performance. The specific gravity of the ash varies inversely as the carbon content, so that this factor can influence the performance of the mechanical collectors. Increased resistivity due to the high carbon or sulfur content of some ash is suspected of reducing the efficiency of separation in electrostatic precipitators, but the point has not been definitely proven.

Plant Experience

Systems in use differ widely and it is presumed there are good reasons in each case for the decisions which were made. In August, 1949, a survey was made by a group of du Pont engineers of 12 plants in Maryland, Pennsylvania, Ohio, New York, and New Jersey. It was found that five of these plants were equipped with mechanical type collectors, four with electrostatic, and three with the combination mechanical-electrostatic. Fly ash was collected dry in five cases, wet in five others, and both wet and dry in the other two. At eight of the plants the ashes were removed from the plant for disposal, whereas in the other four it was settled out in basins on the plant property.

Use of Fly Ash in Concrete

Many concrete technologists throughout the world have studied the possible use of fly ash as a substitute for cement in concrete (2). Fly ash resembles "pozzolana" (natural volcanic ash) in properties, and it has been felt that it would show the same advantages as natural pozzolanic cement. In numerous tests and in actual construction work it has been found that fly ash of proper quality can be substituted for cement up to 25 per cent with certain definite advantages. In general, it has been found that:

1. The water requirement is about the same as that for Portland cement.
2. Fly ash improves the workability of concrete mixes.
3. At 70° F. and less, fly ash concrete develops strength somewhat more slowly, but attains an ultimate strength greater than Portland cement concrete.
4. Fly ash cements have a lower heat of hydration than straight Portland cement concrete and, therefore, exhibit a lower temperature rise.
5. The drying shrinkage is usually less for fly ash cement than for Portland cement, but the effect is small.
6. The addition of fly ash increases the resistance of concrete to the disruptive action of freezing and thawing by 50 per cent or more.
7. Fly ash reduces the formation of silica gel inside the concrete by combining with the free alkali before it has a chance to attack the sand. This results in stronger cement.

At first glance, it is difficult to see why there should be any resistance at all to the use of fly ash in concrete, but there is a logical answer. It takes a long time to test concrete in an actual structure, and failure in concrete work can be very expensive to correct. Then, too, there is the natural resistance to change or tamper with a satisfactory material. The biggest stumbling block, however, is the poor results that have been obtained with fly ash of high carbon content. The maximum carbon content for good performance seems to be about 12 per cent, and a great deal of the available fly ash runs higher.

As evidence that the problem is receiving the attention it deserves, it is noted that fly ash studies are be-

ing carried out by at least seven utilities, four trade associations, two Federal bureaus, the Army engineers, and eight state highway departments. Structures have been built with fly ash concrete and many test sections of roads have been built with it. Reports of its performance seem to be universally good.

Fly Ash in the Bitumastic Road Industry

Another outlet for fly ash has been developed by the Detroit Edison Company; namely, its use as a mineral filler in the bitumastic road industry. This company has spent considerable time and effort in developing an interest in this use for fly ash and has finally succeeded in breaking down the sales resistance to it. It now supplies fly ash under contract to road builders and is equipped to furnish the material in bulk or in bags.

In a paper delivered at a symposium sponsored by the American Society of Mechanical Engineers in New York late in 1949, C. M. Weinheimer (3) of the Detroit Edison Company stated as follows:

"Acceptance of the material on a technical basis is only part of the problem. A great many potential users are antagonistic toward fly ash because they have either heard about the difficulty encountered in handling the material, or already have had unfortunate experience with it themselves. Fly ash is not particularly difficult to handle if the proper equipment is chosen. Difficulty arises sometimes when equipment installed to handle other granular materials is called upon to handle fly ash. No particular difficulty is encountered with pneumatic type of conveyors, but mechanical ones in general require modification or adjustment."

By vigorous promotion and by careful study of the customers' problems, Detroit Edison has been successful in promoting this outlet for the fly ash to the point where, in 1948, 31,200 tons were sold for bitumastic road construction. This was 20 per cent of the total fly ash sold for the year.

Other Possible Uses

One company has cooperated in the development of an excellent insulating cement composed of fly ash, mineral wool, and other material (4). It shows excellent working properties, good adhesion, and almost zero shrinkage. It will successfully withstand temperatures up to 1700° F. The potential tonnage which might find its way into that field has not been estimated.

It has been found that excellent brick can be produced utilizing fly ash and boiler slag. The fly ash must have less than 12 per cent carbon. The properties of the finished brick are superior to those of shale brick in almost all respects.

The same company has prepared a mixture of limestone screenings, fly ash, and hydrated lime for use as a soil stabilization agent. This composition, tentatively given the name "Cor Crete," has been used experimentally as a base course for bituminous and concrete pavements. Final results will not be available for some time, as insufficient time has elapsed for the tests to be completed.

Considerable quantities of fly ash are being used in the foundry trade in place of silica flour as an ingredient of core and molding sand. Several other possible uses for fly ash are worth mentioning in passing—cement and cinder blocks, glazed tile, and sandblasting.

In general, the successful solution of the fly ash utilization problem depends on the construction and road building industry, but it is not an easy solution to reach. Every utility and every industry faced with the problem of fly ash disposal must seek an individual solution to its problem. A

great deal of work remains to be done, but there is every evidence that in many instances economical methods for the disposal of fly ash are in sight.

The foregoing statement applies to those situations where conventional coal burning installations are utilized. The conversion of existing burning units to the horizontal cyclone burner (5) is apparently a solution of the fly ash problem with many types of coal. An exception to this may be with coals of high ash-fusion temperatures where the cyclone burner does not seem to be applicable as yet. Present capacity of these units seems to be in the neighborhood of 200,000 lb. of steam per hour. Other capacities will become available when more experience has been gained with the operation of existing units. The advantage of this burner, in so far as fly ash is concerned, is that nearly all of the ash is discharged from the burner in the molten state as furnace slag essentially free of carbon. The chances of disposing of the furnace slag at a profit are very good.

Acknowledgments

The following papers presented at the fly ash symposium of the American Society of Mechanical Engineers in New York, November 27 to December 2, 1949, have been drawn on freely for the foregoing:

1. "The Present and Future Magnitude of the Pulverized Coal and Fly Ash Disposal Problem," by Henry S. Walker.
2. "Use of Fly Ash in Concrete," by Walter Handy.
3. "The Use of Fly Ash in the Bitumastic Road Industry," by C. M. Weinheimer.
4. "Some New Developments in the Use of Fly Ash," by M. C. Randall.
5. "Reference Bulletin No. 12," Fairmount Coal Bureau (Nov., 1949).

DISCUSSION

By J. Bennett

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As indicated by Mr. Jacobs, the disposal of fly ash is recognized by engineers and plant management as a problem that should be accorded a high priority, not only for its satisfactory solution to management from the viewpoint of economy, but also in the public interest. As the public becomes more conscious of the importance and magnitude of the problem, it will cause increasing concern from that quarter.

Both steam and power are generated at the Front Royal plant of the American Viscose Corporation. For steam generation there is used a powdered fuel system, which of course produces fly ash. Company officials recognized the fly ash disposal problem from the beginning of the Front Royal plant operations and, therefore, included this project with the sewage disposal system. Improvements have been made to the point that it is felt the situation is being satisfactorily handled. A general description of the system is as follows: The ash-laden gases from the boilers, before going to the stack, are routed through cyclones, which separate most of the fly ash from the gases. This prevents the ash from settling over adjacent areas. Water is added to the collected fly ash and the slurry is pumped through 1,800 ft. of pipe to the settling or decanting basins. These basins are equipped with stand pipes, which allow the ash to settle and decant the water flow to the river. The water going to the river is, for all practicable purposes, free of all fly ash and has an

TABLE I.—Settling Basin Data for Fly Ash Removal

Basin No.	Year Constructed	Cost ($)	Capacity (cu. yd.)
1	1947	2,724	—
1[1]	1949	4,484	60,000
2	1947	2,724	20,000
3	1948	7,247	25,000
Total	—	17,180	105,000

[1] Extended.

analysis almost identical with the river water.

Fly ash is damaging to a stream only because it settles on the river bottom and smothers all plant and animal life. Except for this smothering, it has no effect, chemically or biologically.

The three large settling basins at the Front Royal plant were built by bulldozer excavation, using the excavated dirt to form the enclosing banks. Data on construction costs and capacity of the basins is given in Table I. Based on an ash density of 60 lb. per cu. ft., the three basins provided storage for the equivalent of 14 acre-ft. per year, at an initial cost of $0.164 per cu. yd.

Approximately 216,500 tons of coal are burned per year, producing 19,500 tons of fly ash, including slag. On an annual basis, fly ash disposal costs are as follows:

Power	$2,300
Water	455
Retention basins	2,475
Total	$5,230

This amounts to $0.024 per ton of coal, or $0.27 per ton of ash. When depreciation is included, fly ash disposal cost amounts to about $0.86 per ton. For each pound of fly ash 4.5 gal. of water are required.

At the Lewistown, Pa., plant of this same company, it costs $1.00 per ton to move fly ash because of the hauling distance involved. At other plants of the company at least $0.50 per ton is realized from the sale of stoker ash.

Mr. Jacobs states that with stokers the quantity of fly ash reaching the stack will be 25 to 50 per cent of the total ash. Our engineers advise that only 10 to 20 per cent reaches the stack. Also, our power engineer does not agree on the particle size of quantities emanating from stokers. For single retort, multiple retort, chain grates, and underfeed stokers, the particle size of fly ash is usually less than 5 per cent under 10 microns, and less than 20 per cent under 40 microns, instead of 20 to 40 per cent below 10 microns as stated by Mr. Jacobs. Some 80 to 90 per cent will be less than 200 microns.

Mr. Jacobs has said that there are only two reasons for the installation of dust collectors—the maintenance of good public relations, and the existence of ordinances requiring it. Another very good reason is that the induced draft fans conveying the boiler gases through the collectors would not last any time, due to abrasion by ash in the air handled by the fan. This would result in excessive repairs and maintenance, and possible boiler outages.

Mr. Jacobs briefly describes the several types of equipment for fly ash collection. It is becoming more evident that the trend is toward use of both mechanical and electrostatic types in series. This is particularly true in public utilities, where the combination is almost imperative. The electrostatic devices, which inherently have low velocities, are most efficient on the smaller particles, especially on reduced loads. They are highest in efficiency where the mechanical collector falls down. Also, the mechanical collector is most efficient on the larger particles at high rates of gas flow, as well as at higher ratings, so the combination gives virtually a straight-line curve that can be made up to 97 per cent efficient on the total fly ash.

Although it is true that fly ash is being used in concrete, cinder-blocks, etc., it is very much doubted if industry will ever be able to use more than a comparatively small fraction of the fly ash that is collected from large industries and central stations, which use fly ash collecting systems. The trend to pulverize fuel, and therefore more fly ash, is becoming stronger all the time, which makes the fly ash problem more acute.

WASTE CONTROL TO CONSERVE WAR METALS

Waste control measures that not only will curb pollution of streams but also will aid in conserving metals important to national defense are to be drafted by the metal-finishing action committee of the Ohio River Valley Water Sanitation Commission, which met in Cincinnati, Ohio, on July 26, 1950. The committee is composed of representatives of top management in the electroplating industries in the Ohio valley.

The war emergency is said to accent the efforts of this committee and the Commission in promoting control of industrial waste. A manual of plant practice is being developed for electroplating establishments with a view toward curtailment of wastes that may cause pollution of streams. This will also point to salvage of metals and solutions now being wasted that are likely to be in short supply because of the war.

Better "housekeeping" methods, which will be outlined in the manual, are expected to reduce pollutional discharges from some plants by as much as 50 per cent. This alone will represent an important contribution to stream clean-up efforts.

In addition to the preparation of the manual, the metal-finishing group appointed sub-committees to evaluate present waste treatment methods, outline ways of conducting plant waste surveys, study toxicity potentials of various wastes, and develop standard analytical procedures.

Stream Pollution

PERSISTENCE OF CHLOROPHENOLS IN POLLUTED RIVER WATER AND SEWAGE DILUTIONS *

By M. B. Ettinger and C. C. Ruchhoft

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The factors determining the persistence of phenol and cresols in surface waters have already been studied and reported (1). Briefly, it was found that phenol and cresols are dissipated in surface waters by biological oxidation. The persistence of these materials appears to be governed by those factors which determine biological oxidation rates.

Further studies of the persistence of individual materials appear to be much needed. There can be no better way to improve the over-all knowledge of self-purification factors than to study the persistence of individual compounds. Ortho- and para-chlorophenols were chosen for early study because adequate analytical methods, sensitive to a few parts per billion of these materials, already were available (2).

However, as these chlorinated phenols are likely to be of infrequent occurrence in surface waters, they have been investigated on a limited scale at 20° C. Enough work was undertaken to give a fair indication of the behavior that might be expected from these organic compounds.

Analytical Techniques

The analytical technique used in the study was a modification of the Gibbs method as previously described (2). Para-chlorophenol does not give a very intense reaction using this technique. Apparently this is because the reagent first has to dechlorinate the para-chlorophenol and react with the resultant phenol. The color is produced more slowly and the final intensity is lower than would be obtained with an equivalent amount of phenol. In the case of ortho-chlorophenol, the reaction appears to be relatively rapid. For this chemical, the reaction has a linear range for concentrations apparently extending well beyond 100 p.p.b.

The wave-lengths used for quantitative measurements on a Beckman spectrophotometer were 670 millimicrons for para-chlorophenol, and 690 millimicrons for ortho-chlorophenol.

Some attempts were made to use ultraviolet absorption measurements, rather than the Gibbs reaction, as a basis for the analytical measurements. However, the ultraviolet observations appeared to be less satisfactory than the procedure in the visual range. One of the principal difficulties was the high background ultraviolet absorption noted in the distillate from polluted river samples. In attempting analytical examination of polluted river samples, the absorption due to chlorinated phenol appeared superimposed upon that due to other materials distilled from acid solutions of the river water. Furthermore, the

* Presented at 1950 Annual Meeting, Central States Sewage Works Assn.; Indianapolis, Ind.; June 9–10, 1950.

absorption of ultraviolet radiation caused by other materials in the polluted water was not necessarily constant for the duration of an experiment. It appeared, therefore, that measurement of the absorption by the more specific colors developed by the Gibbs reagent was the more satisfactory method of testing for the chlorophenols in question.

Persistence Data

In the first persistence experiments, ortho- and para-chlorophenol were added to 1 per cent dilutions of sewage in standard B.O.D. dilution water. Two series of observations for periods up to 25 days at 20° C. were made on each of these chlorophenols. The data obtained in these studies are given in Table I. In three of the series of observations, no dissimilation of the chlorinated phenol appears to have taken place, at least not within the accuracy of the analytical measurements. In the fourth case, apparently para-chlorophenol was slightly attacked in one sewage dilution in 23 days.

The preliminary experiments led to the belief that these chlorophenols were relatively immune to biochemical attack. Further investigation showed that such was not the case. The next experiments consisted of adding 1 p.p.m. of ortho- and para-chlorophenol to relatively polluted river waters. The results are given in Table II. It may be seen that these materials were attacked much more rapidly when added to the river water than when added to the sewage dilution. The more rapid attack is probably due to the presence in the river water of microorganisms capable of destroying ortho- or para-chlorophenol.

Although these chlorophenols were removed much more quickly from the river waters than from sewage dilutions, the over-all persistence was much greater than was found for phenol and cresols under similar circumstances (1).

Next, the effect of seeding was investigated. Parallel studies were made of the persistence of ortho-chlorophenol added to two river waters, with and without seeding. In one case, the ortho-chlorophenol was simply added to the river water. Concurrently, another portion was prepared in which the same concentration of the ortho-chlorophenol was introduced along with a small amount of seed. The seed used consisted simply of some river water from a prior persistence experiment, and presumably introduced a number of organisms which attacked

TABLE I.—Persistence of Para- and Ortho-Chlorophenols in B.O.D. Dilution Water Containing 1 Per Cent Domestic Sewage at 20° C.

Storage Period (days)	Residual Chlorophenol (p.p.b.)			
	p-Chlorophenol		o-Chlorophenol	
	Exp. 1	Exp. 2	Exp. 3	Exp. 4
0	1060	—	1130	—
1	—	960	—	1120
3	1300[1]	—	1110	—
8	—	980	—	990
10	980	—	810	—
15	—	880	—	1000
17	920	—	1020	—
23	—	650	—	960
25	1000	—	930	—

[1] This value questionable.

TABLE II.—Persistence of Mono-Chlorophenols Added to Surface Waters at 20° C.

Storage Period (days)	Residual Mono-Chlorophenols (p.p.b.)			
	Great Miami River Water		Little Miami River Water	
	o-Chlorophenol	p-Chlorophenol	o-Chlorophenol	p-Chlorophenol
0	980	1,000	890	1,000
6	810	980	870	1,000
13	790	80	480	0
15	760	0	0	0
23	710	0	0	0
36	0	0	0	0

TABLE III. — Persistence of 1,000 p.p.b. Additions of Ortho-Chlorophenol in Surface Waters

Storage Period (days)	Residual Ortho-Chlorophenol (p.p.b.)			
	Great Miami River Water		Little Miami River Water	
	Unseeded	Seeded[1]	Unseeded	Seeded[1]
0	1,000	1,000	1,000	1,000
1	—	800	930	730
5	900	600	890	690
6	700	580	550	620
8	650	300	570	200
13	610	10	20	80
15	320	—	—	0
19	30	—	—	—

[1] Seed consisted of ½ ml. per liter of 0.5 ml. of seed per liter of river water.

the chemical. The results are given in Table III.

The addition of the seed reduced the persistence of the ortho-chlorophenol in the case of one of the river waters in this series of experiments. However, the unseeded experiments of Table II show about the same over-all persistence of ortho-chlorophenol as is shown in the seeded samples of Table III. This indicates that although the seed is important, it is by no means the only factor.

Discussion of the Data

Throughout this paper, it has been assumed that biochemical action is responsible for the dissipation of the chlorophenols studied. There are a number of reasons for accepting this premise:

1. Previously (1), it was demonstrated that phenol is quite stable in sterile solutions, but is rapidly attacked in the presence of a suitable microflora.

2. The data definitely point toward biochemical dissimilation as the mechanism whereby the chlorinated phenols are dissipated.

3. No other mechanism can be postulated which is consistent with all the observations.

The chemical nature of the mono-chlorophenols suggests that the number of species of microorganisms which will attack these materials is highly limited. The data presented are definitely in accord with this premise. It is interesting to note that two samples of sewage failed to yield organisms capable of attacking these materials within a reasonable period of time. On the other hand, both river waters apparently contained such a seed.

The general implications of the study are plain:

1. Ortho- or para-chlorophenol may be attacked by biological agencies in a surface water.

2. The attack on such material, even under favorable conditions, will proceed at a slow rate.

3. Ortho- or para-chlorophenol may persist for long periods if discharged occasionally into a relatively pure stream. However, it would appear likely that a bacterial flora capable of destroying these chlorophenols would soon be established if the wastes are discharged regularly.

Summary and Conclusions

It has been shown that low concentrations (1,000 p.p.b.) of ortho- and para-chlorophenol, when added to the ordinary dilutions of domestic sewage, were not always removed in periods of 20 to 30 days at 20° C. Similar concentrations of these mono-chlorophenols were removed at this temperature during similar periods of storage when added to polluted surface waters. These observations on the conditions required for dissipation of mono-chlorophenols in surface waters and sewage dilutions, together with previous observations on the similar dissipation of cresols and phenol, indicate that biochemical dissimilation is responsible for the removal of these

materials. The study has also shown that the removal of these mono-chlorophenols requires the presence of a specialized microflora and, in general, proceeds at lower rates than the similar removal of cresols and phenol.

Acknowledgment

The authors wish to acknowledge the assistance of R. J. Lishka, who helped with the analytical observations in this report.

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WASHINGTON ADOPTS MINIMUM REQUIREMENTS FOR CONTROL OF INDUSTRIAL WASTES

The Washington State Pollution Control Commission on August 3, 1950, adopted "Minimum Requirements for the Control of Industrial Wastes" (see THIS JOURNAL, **22**, 4, 514; Apr., 1950).

The "requirements," which are actually fundamental procedures for in-plant prevention and reduction of industrial waste discharges, are to be used as guides to the Commission staff in the industrial waste control program. They were drafted by E. F. Eldridge, Director and Chief Engineer, Washington State Pollution Control Commission and Kenneth H. Spies, Chief, Water Pollution Control Section, Oregon State Sanitary Authority, acting as a committee of the Water Pollution Control Council, Pacific Northwest Area. The Council includes representatives of pollution control agencies in Montana, Idaho, Oregon, Washington, British Columbia, and Alaska.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

FINANCING EQUIPMENT REPLACEMENT

Enviable, indeed, is the unusual provision of the sewage plant financing program at Kenosha, Wis. (described elsewhere in this issue of The Corner), where a depreciation reserve account is set up, under state regulations governing utility accounting, to pay for replacement of worn out plant equipment and structures. How many times have superintendents and operators faced the problem of major replacements—or, for that matter, even minor ones—only to run up against the blank wall of having no funds available?

Provision of a depreciation reserve is recognized by industry as being nothing more than good business. Other public utilities, in most cases, not only are allowed to accumulate such reserves, but also are required to do so by State Public Service Commissions. Nevertheless, despite its actual public utility aspects, sewage service continues to be regarded as a municipal function and not as a public utility. In the final analysis this means that many of the advantages available in operation and financing as a utility are denied to sewage service agencies.

In several states, legal obstacles stand in the way of sanitary districts, etc., desiring to set up reserve accounts. In all but a few instances, sewage works financing is dependent on tax levies, either directly or through the medium of a general tax account. Most of the legal bars are based on the premise that tax revenues must be used for current operation, maintenance, and retirement of existing debt, and not for future replacement of capital items. Under existing conditions no way can be seen to lay aside that rainy-day nest egg for equipment and structure replacement when needed.

There is, however, a bright spot on the horizon. The present trend toward making sewage facilities self-supporting—through sewer rental charges—bids fair to be a major step in the direction of recognized utility status. Herein, apparently, lies the greatest hope of providing a means of establishing "retirement" funds for overage equipment and structures.

Is it logical that water, power, and similar services should be allowed or even required to accumulate "old age security" funds for outmoded or worn out facilities while sewage service organizations are denied the same right?

H. P. O.

FOR THAT RAINY DAY—A DEPRECIATION RESERVE

By Frank I. Vilen

Superintendent, Sewage Treatment Plant, Kenosha, Wis.

About 1938, when Kenosha, Wis., was faced with the necessity of constructing a sewage treatment plant, the principal question was, "How can the project be financed?" The community, like many others, was still staggering from the effects of the depression and. even with large amounts of Federal aid pouring into the city, the financial picture was very gloomy. A Public Works Administration grant was available, but there still remained a sizeable sum to be raised for the city's share of the cost.

One of the municipal functions which had withstood the lean years in fair condition was the Water Department, a municipally owned corporation. Could and would the Water Department assume the cost of constructing a sewage treatment plant? It could, provided the plant was called a "Water Supply Protection Works"—a pretty good name for a sewage treatment plant—and provided operation of the plant was made subject to the laws of the State of Wisconsin and the regulations of the Wisconsin Public Service Commission governing the financing and operation of utilities.

As the City was willing to conform to these provisions, the Wisconsin Public Service Commission granted the Kenosha Water Department permission to finance the project. Waterworks revenue bonds for the City's share of the cost were issued and, in due time, the sewage treatment plant became a part of the water utility. Incidentally, the Water Department's investment and indebtedness in the sewage treatment plant is a consideration in the determination of the water rate structure.

As a public utility, the Kenosha plant is subject to certain regulations which make it extremely unusual among sewage works. Accounting, for example, must follow a prescribed procedure established by the Public Service Commission. The thing liked best, however, (and the gist of this article) is the fact that a depreciation reserve account is provided. Each year a budget estimate of operation costs is submitted and funds for the operation of the plant are appropriated from the general tax levy by the City Council. The budget includes an annual sum placed in reserve and calculated to pay for replacing worn out plant equipment and structures on the basis of original cost and after an estimated life. The reserve account equals approximately 19 per cent of the total annual operating budget; in other words, out of every dollar spent for sewage treatment in Kenosha, 19 cents is set aside to replace worn out items.

That this is good business, no one will deny. As an example, last year replacement equipment was purchased in the amount of $7,700. Of this total, $6,450 was charged to depreciation reserve. The balance, $1,250, represented increases over the original cost and was carried in the budget as an equipment replacement item. A good example of putting something aside for a rainy day!

It may interest other operators to see how the Kenosha plant's operating costs are distributed. The following tabulation shows the major items and

the percentages they represent of the total appropriation:

Item	Proportion of Total Appropriation (%)
Engineering and supervision	8.2
Wages and salaries	44.7
Fuel and power	6.1
Maintenance, struct. and equip.	4.6
Materials and supplies	9.7
Depreciation reserve	19.1
Retirement fund	5.2
Miscellaneous	2.4
Total	100.0

The Kenosha plant is most fortunate in having a depreciation reserve account. It is good business to have the money available when it is necessary to replace any of the equipment. It is believed that such an account should be a part of the financial structure of any treatment plant, and certainly should be included in the arrangements for all new plants.

REGULATION OF INDUSTRIAL WASTES ENTERING WESTCHESTER COUNTY (N. Y.) SEWERS *

By James C. Harding

Commissioner of Public Works, Westchester County, New York

Westchester County, New York, lies just north of New York City. It has an area of 457 sq. mi., an estimated population of 630,000, and an assessed valuation of $1,630,000,000. The County is divided into 6 cities, 22 villages, and 18 towns. The contour of the County is rather rugged, varying in elevation from sea level to 980 ft.; drainage is to the Hudson River on the west and to Long Island Sound on the south.

The first trunk sewer built by the County was the Bronx Valley sewer, construction of which was started in 1909 under special legislation limited to this particular sewer. In 1926, general legislation was obtained allowing the County to construct trunk sewers and sewage treatment plants wherever needed.

It is probable that Westchester County became the first New York county to build a trunk sewerage system because of the relatively heavy population drained by small streams furnishing very limited dilution. Individual plants, even if well designed and operated, would have caused extensive stream pollution. Land values were uniformly high, thus increasing the probable cost of individual treatment plants and the damage that might be done by them. Some municipalities are located in several drainage areas, which would have necessitated large expense for pumping, or the construction of a large number of plants.

Another important factor that impelled construction of county trunk sewers was the desire to clean up the streams in order to construct a parkway system along their banks. Naturally, streams polluted with sewage or sewage plant effluent would have had no place in public parks.

The Westchester County sanitary trunk sewer system is divided into 9 separate assessment districts. There are 108 mi. of trunk sewers varying in diameter from 10 to 78 in., 10 pumping stations, 18 regulators, and 4 sewage treatment plants varying in capacity from 12 to 84 m.g.d. The cost of constructing the system was $25,000,000.

* Presented at 1950 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Jamestown, N. Y.; June 12–13, 1950.

Sewage Characteristics

Westchester County is largely a residential area. The sewage does not contain any large proportion of industrial wastes, as the larger industries are located along the Hudson River and many of them discharge their industrial wastes directly therein. The sewage is stale when it arrives at the plants, due to the long trunk lines, but is otherwise a dilute domestic sewage. An average analysis would be about as follows:

pH	7.2
Suspended solids	140 p.p.m.
Settleable solids	105 p.p.m.
Total solids	245 p.p.m.
B.O.D. (5 days)	130 p.p.m.

Previous Experience

In view of the fact that the sewers are not called upon to care for any large quantity of industrial wastes, it might be asked why Westchester took the initiative in preparing a code, or rules and regulations, to govern the quantity and character of its sewage. The reasons are simple. Concern was felt about industrial wastes increasing the volume of sewage to be cared for by the interceptors and treatment plants, the effect of certain kinds of wastes on the physical structure of the sewers and appurtenances, and the effect of industrial wastes on the cost of present and future sewage treatment. That the concern was justifiable is indicated by the following examples:

Regulation of Flow

A chemical company, located on the banks of the Saw Mill River about 3 mi. above the intake of the Yonkers water works, for a number of years discharged its industrial wastes, amounting to some 2.2 m.g.d., into that river. On quite a few occasions it was necessary for Yonkers to close down its plant and to purchase water from New York City at a cost of several hundred dollars a day because, at least in the opinion of the City, the industrial wastes changed the character of the river water to such an extent that, even with slow sand filtration, it could not render the water palatable.

State Conservation Department inspectors, after a number of investigations, were of the opinion that the wastes from the chemical company were responsible for a large number of dead fish found floating in the river below the point of discharge. The chemical company claimed that its industrial wastes were not at all harmful, as the concentration of chemicals therein was not sufficient to cause any trouble. The Health Department, the City of Yonkers, and the chemical company, all requested that the discharge of all of this industrial waste into the trunk sewer be permitted.

County authorities were much concerned when the application for service was received. Although the chemical company was a large payer of sewer taxes, the Yonkers water supply certainly deserved protection. However, acceptance into the County sewer of a volume of industrial waste equivalent to the discharge of sewage from a population of 20,000, even though ample capacity was available at the time, was thought to be inadvisable.

After several conferences, and a study of the wastes by a consulting chemist hired by the County Public Works Department for that purpose, it was found possible, by making minor changes in piping within the plant, to reduce to about 0.2 m.g.d. the amount of waste containing chemicals that could possibly cause trouble in the stream. The remaining 2-m.g.d. flow was discharged back into the stream. By this procedure, not only was 2 m.g.d. of sewer capacity saved, but also the City of Yonkers received an equivalent amount of water back in the stream and available for water supply.

This incident pointed up the advisability of taking all possible steps to

cut down on the amount of wastes discharged by industry into the sewerage system.

Regulation of Wastes Characteristics

One bad experience had been caused by sulfuric acid wastes from a wire mill finding their way into the sewer. In 1941 it was noticed that two sewage pumps that had formerly given good service were causing considerable trouble. Packing sleeves, impellers, and even the pump casings, seemed to demand frequent repairs and replacements. County engineers, assisted by mechanics from the pump manufacturer, tried to uncover the reason for the trouble. Finally, a portable pH indicator installed in the pump discharge line showed pH readings as low as 3.0 during working hours, from 3.0 to 6.5 during non-working hours, and from 7.0 to 7.5 on Sundays.

By successive elimination of sewers leading to the pumping station it was found that drainage from pickling vats was getting into a 12-in. cast-iron sewer. When dug up, the pipe was found to be completely disintegrated in places. As a result, it was necessary to reconstruct the sewer, install new pumps, and make sure that the drainage from the vats was led elsewhere. This example showed the importance of keeping corrosive industrial wastes out of the sewage.

For a couple of years concern also has been felt about the industrial waste from another manufacturing company. This waste, amounting to about 1.5 m.g.d., discharges into a municipal sewer and thence through a County trunk sewer to one of the County treatment plants. The waste contains the discharge from wool washing machines, dye vats, and wool rinsing equipment.

On occasions it had been noticed that the influent at the treatment plant several times a month possessed a strong odor and color and contained a large amount of sediment. It also was noticed that several times a day a chlorine residual was unattainable, because of the abnormally high chlorine demands, despite chlorine dosage at a rate of 3,750 lb. per day, the maximum output of all the chlorinators.

After a rather extensive investigation the source of this difficulty was found. Conferences with the operators of the factory resulted in their installing a fill and draw settling tank so that the rate of discharge would be more regular. Instead of peak chlorine demands of from 30 to 60 p.p.m., the range is now from 20 to 30 p.p.m., which can be handled without too much difficulty with available chlorination facilities. We are not yet satisfied. However, an endeavor is being made to get the manufacturer to reduce the chlorine demand of the waste before discharging it to the sewer. This manufacturer is a large sewer taxpayer. On the other hand, during certain periods of the year his waste discharge increases the County bill for chlorination by from $12 to $15 per day. This example illustrates the necessity of prohibiting the discharge into the sewers of industrial wastes likely to increase the cost of operating the treatment plants and also increase operating difficulties.

Code as Adopted

The County code, or rules and regulations, is divided into several sections as follows:

1. A general section setting forth general terms and definitions.
2. Instructions for the preparation and submission of applications for connections to County trunk sewers.
3. Requirements and specifications governing the construction of the connections themselves.
4. Regulations governing the discharge of sewage, industrial wastes, and other wastes to the trunk sewers. This last section is set forth below.

WESTCHESTER COUNTY, N. Y., RULES AND REGULATIONS GOVERNING DISCHARGE OF SEWAGE, INDUSTRIAL WASTE AND OTHER WASTES TO COUNTY SEWERS

I. General Purposes of Regulations

These rules and regulations have been formulated and are set forth herein for the guidance of all persons causing the discharge or desiring to discharge, sewage, industrial waste or other waste into the County sewers either by direct connection or through the sewers of local municipalities. These rules and regulations are subject to review and modification or revision at any time or for any particular application for connection and in general represent only the minimum characteristics of sewage, industrial waste or other waste which will be acceptable as a contribution to the County sewerage system.

Specifically stated, the general purpose of these rules and regulations are:

(a) To prohibit excessive volumes and/or inordinate rates of flow of sewage and wastes into the County sewerage system.

(b) To prohibit the contribution of sewage, industrial wastes or other wastes which may cause maintenance difficulties in the sewers, force mains, pumping stations, sewage regulators and other structures appurtenant to the County sewerage system.

(c) To prohibit the contribution of sewage, industrial waste or other waste which may create operating difficulties at the sewage treatment plants as they now exist or may be constructed or modified in the future.

(d) To prohibit the contribution of sewage, industrial waste or other waste which require for treatment at the plants greater expenditures than are required for equal volumes of raw domestic sewage.

(e) To require the treatment, before introduction into the County sewerage system, of such wastes as may otherwise impair the strength and/or durability of the structures appurtenant to the system, by direct or indirect chemical action.

(f) To provide cooperation with other agencies which have requirements for the protection of the physical, chemical and bacteriological quality of water courses within or bounding the County.

(g) To protect the public health and to prevent nuisances.

II. Sewage

"Sewage" means the water-carried human or animal wastes from residences, buildings, industrial establishments, or other places, together with the minimum of such ground water infiltration and surface water as may be present. The admixture with sewage as above defined and wastes or other wastes as hereafter defined, shall also be considered and may be termed "sewage."

1. No snow, storm, cellar, surface or roof water or other drainage water shall be discharged through a connection to the County sewerage system.

2. The discharge of sewage through a connection shall not exceed 150 gallons per day per capita of connected tributary population and shall at no hour exceed a rate of 300 gallons per day per capita of connected tributary population.

3. If the daily volume and/or rate of flow through a connection as determined by this Department exceed the maximum limits set forth above, the Applicant or Owner of the connection may be requested to change, modify or improve the flow characteristics of his sewage contributions so that these standards are met.

4. In the event that the limiting standards of flow are not obtained within a reasonable time, the use of the connection may be denied or modified by this Department until such time as the conditions are remedied.

III. Industrial Waste

"Industrial Waste" means any liquid, gaseous, solid or other waste substance or a combination thereof resulting from any process of industry, manufacturing, trade or business or from the development or recovery of any natural resources.

1. The following standards have been adopted to control the quantity and quality of industrial waste which may be discharged through a connection into the County sewerage system.

(a) The Department shall determine and establish the maximum volumes and rates of flow for each Applicant or Contributor based on the conditions as found and maintained.

(b) The Department reserves the right to require that permanent provisions be provided for measuring continuously or intermittently, industrial waste contributed to the County sewerage system.

The metering devices may consist of weirs, Venturi tubes, Kennison nozzles or other approved devices, equipped with recorders and totalizers, to be provided and installed by the Applicant, Owner or Contributor as required by this Department.

Where necessary, detention tanks may be required to reduce the maximum rate of discharge to such percentage of the average 24-hour rate of discharge as directed.

(c) Industrial wastes shall contain no solids in solution which will precipitate greater than 1,000 p.p.m. upon acidification (pH below 5.5), or alkalization (pH above 8.5) or oxidation or reduction.

(d) Viscosity of industrial wastes shall not exceed 1.10 upon discharge or after acidification or alkalization, etc., as outlined immediately above.

(e) The temperature of industrial wastes upon discharge shall be within the limits of 32 and 150 degrees F.

(f) The color of industrial wastes shall not exceed an intensity of 500 p.p.m. Samples shall be diluted with distilled water to bring the range within 10 to 50 p.p.m. and judged on a basis of "intensity" or transmission of light rather than "true color" (Platinum Cobalt Standard).

(g) The limiting chemical characteristics of receivable industrial wastes shall be as follows:

B.O.D. 5-day, 20° C.	400 p.p.m. (max.)
Chlorine demand (30 min., room temperature)	25 p.p.m. (max.)
Suspended solids	300 p.p.m. (max.)
Settleable solids (Imhoff cone test, 1 hour)	10 ml./liter (max.)
Hydrogen ion concentration (pH)	4.5 to 9.5

IV. Other Wastes

"Other Wastes" means garbage, refuse, decayed wood, sawdust, shavings, bark, sand, lime, cinders, ashes, offal, oil, tar, dye stuffs, grit, abrasives, metal filings, trimmings, etc.

1. The inclusion of any of these materials or any other materials of a similar nature in the sewage contributed to the County sewerage system will not be tolerated.

2. They shall be completely eliminated from the sewage at the source, and before the sewage is discharged into the County sewerage system.

V. Undesirable Chemicals or Chemical Compounds

The following chemicals or chemical compounds are undesirable in any sewage contributed to the County Sewerage System.

1. Alcohols; Arsenic and Arsenicals; Bromine, Chlorine in excess of 100 p.p.m.; Copper and Copper Salts; Cresols; Fluorine; Formaldehydes; Iodine, Mercury and Mercurials; Phenols and their derivatives; Silver and Silver Compounds, Sulfonamides, Toxic Dyes (organic or mineral); Zinc; all strong oxidizing agents such as Chromates, Dichromates, Permanganates, Peroxide, etc.; Greases and Oils; compounds producing Hydrogen Sulphide or any other toxic, inflammable or explosive gases, either upon acidification, alkalization, oxidation or reduction; strong reducing agents such as Nitrites, Sulphides, Sulphites, etc.; Inflammable or Explosive Liquids or Solids.

2. The above mentioned chemicals or chemical compounds or those of a similar nature shall be eliminated from any sewage to be contributed to the County sewerage system or reduced by treatment at the source to a concentration which will meet the general purposes of these rules and regulations; or come within the applicable standard stated elsewhere herein; and which will not adversely affect sludge digestion or any other biochemical or biological process normal to sewage treatment plants.

3. The concentrations of any of the undesirable chemicals or chemical compounds which may be permitted for inclusion in sewage discharged to County sewerage system shall be fixed by this Department unless otherwise stated.

VI. Holding Tank

This Department reserves the right to require the Applicant, Owner or Contributor to provide at any time a sedimentation tank of sufficient size and depth to reduce the suspended solids in the sewage to the maximum limit set forth above.

VII. Chlorination

In cases where the sewage contributed to the County sewerage system contains viable pathogenic bacteria in quantities larger than normally encountered in raw domestic sewage, this Department reserves the right to require chlorination.

VIII. Disposal of Garbage

Under no circumstances will the discharge of unshredded garbage or refuse into a County trunk or into a connecting municipal or private sewer be permitted.

Shredded garbage or refuse resulting from the normal occupancy of any building and only that of the actual occupants of the building, shall only be discharged into the sewers with the prior express approval of the local municipal authority having jurisdiction.

Where no local requirements for comminuted garbage or refuse are established, and/or supplementing and clarifying existing local requirements, the following regulations shall always prevail and be rigidly enforced:

(1) Only food wastes shall be considered as garbage,

(2) All shredded particles shall be of such size that they will be carried freely under the flow conditions normally prevailing in sanitary sewers, and

(3) All shredded particles shall have no dimension greater than one-half inch.

IX. Treatment Before Point of Discharge

All the treatment or measurement of sewage required by this Department pursuant to these rules and regulations and/or as determined and fixed for particular conditions, shall be accomplished to practical completion before the point of discharge of sewage into a public sewer, whether part of the County sewerage system or part of a local municipal sewer connecting thereto.

X. Control of Odors

The control of all odors emanating from a connecting sewer shall at all times be the responsibility of the Owner of the connection. He shall take all necessary steps to eliminate undue odors at their source or to install means and methods such as traps, draft stacks, flap valves or other devices to prevent the discharge of offensive odors into the County sewers or the entrance of odors from the County sewer into the connecting sewer. The costs of such devices and all attendant expenses shall be borne solely by the owner.

It is still too early to state just how the code will work out. It is realized that in order to get any good out of a code, it must be enforced. It is realized further that such enforcement cannot be made effective if the Department is the only agency interested. By and large the County Public Works Department is not familiar with the industrial plants and other sources of unusual wastes that contribute to local sewers and eventually to those under county jurisdiction. It is believed, however, that with the assistance of the Department of Health and that of local plumbing inspectors and other municipal officials at least a good start can be made in decreasing excessive volumes of industrial wastes and in keeping out such wastes as will hasten disintegration of county sewers and other facilities, or increase the cost and difficulty of sewage treatment. Promulgation of the code has at least provided a yardstick with which to measure the desired results.

Acknowledgment

In the writing of the code discussed herein, the Westchester County authorities were very materially aided by Thomas M. Riddick, consulting engineer, New York City.

BAR SCREEN ODOR CONTROL

By James E. Frook and Elmer Pollex

Chemist and Chief Operator, respectively, Sewage Treatment Works, Toledo, Ohio

The Toledo, Ohio, sewage treatment plant is equipped with two mechanically raked bar screens, which are housed in the detritor building. In their natural course of operation the screens have proved offensive to both the eye and the nose, particularly those of the visitor. First impressions are important someone has said; therefore, corrective measures were taken.

To the existing equipment was added a completely enveloping cover of sheet aluminum. Except for a ⅛-in. thick panel made to slide horizontally on the front of each screen, all sheets were of 1/16-in. thickness. Aluminum was used for lightness and durability. The interior of the finished cover was painted with a bituminous corrosion-resistant paint; the exterior with a clear varnish similar to linoleum varnish.

The cover, excepting the sides, is in three sections, all of which are hinged. One of the cover sections is opened regularly for inspection and cleaning purposes. It is counter-balanced sufficiently to maintain its position, whether open or shut (Figures 1, 2, and 3). An automatic switch, located on the outside of the side covers, turns on two electric lights beamed onto the bar screens when the cover is lifted and shuts the lights off when the cover is closed.

The ventilating problem was solved by installing ducts from the rear of each bar screen cover and joining them in a common duct under the floor to a ventilating fan placed about 7 ft. above the floor. The interior of these ducts is coated with the same paint as the interior of the covers. A fan capable of discharging 3,000 c.f.m. exhausts the air through a 13-in. by 18-in., 5-louvered shutter. The original louvers lasted about a year before failure. They have been replaced with

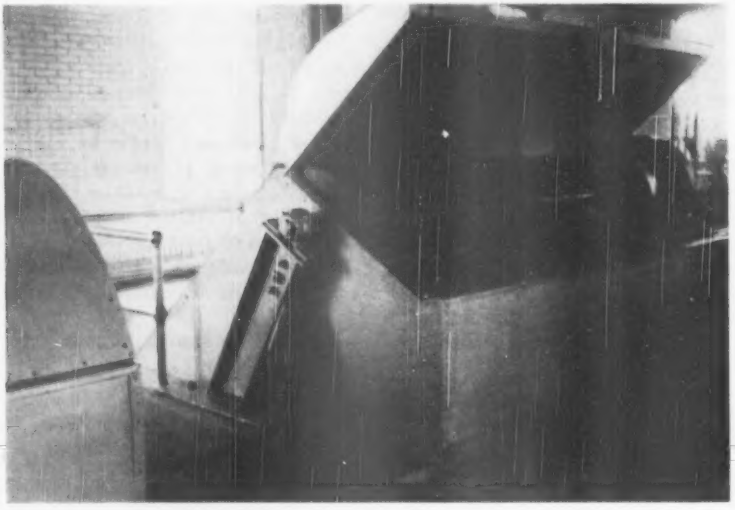

FIGURE 1.—Front side view, cover open.

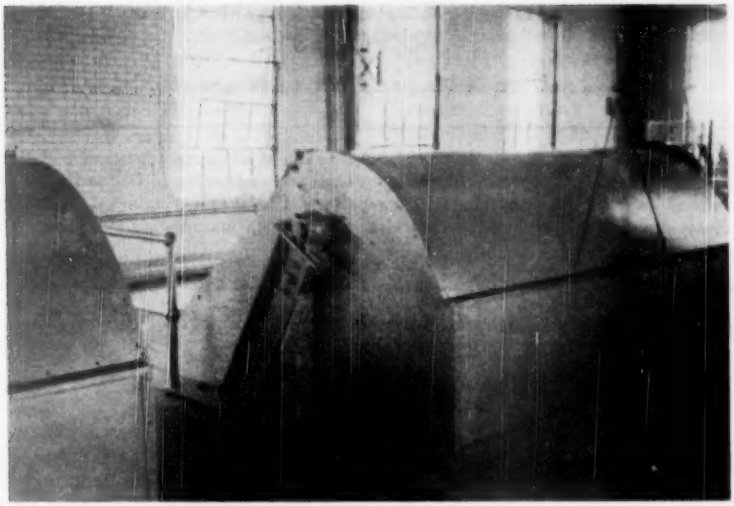

FIGURE 2.—Front side view, cover closed.

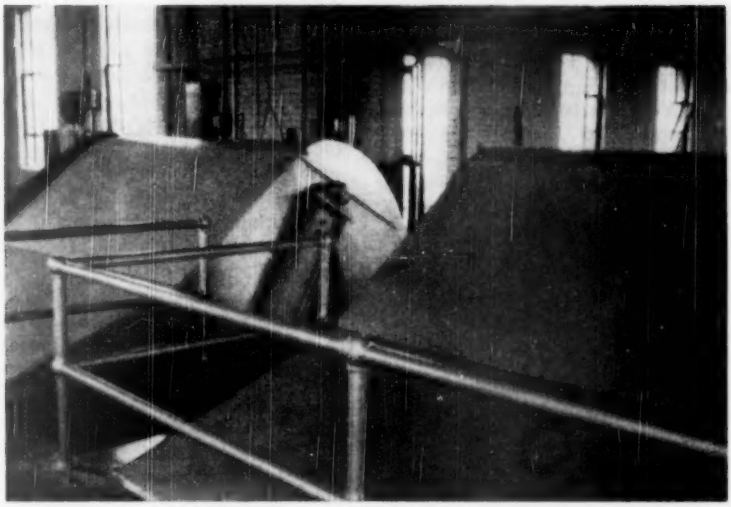

FIGURE 3.—Rear side view, cover in place.

stainless steel louvers, and with satisfactory results.

As the fan runs continuously, there is constant removal of objectionable odors from the detritor building. Even when the covers are lifted for display purposes, there are no odors of any consequence.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"I love fools' experiments; I am always making them."—*Darwin*

Attention operators! **It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.**

Annual Report of the Sewage Works Manager, Borough of Slough, England, for the Year 1949–50 *

By M. A. Kershaw, *Manager*

Treatment

The strength of the sewage remains substantially the same as in 1948–49, when a very noticeable increase in strength over previous years was recorded. This, combined with the increased volume of sewage received, placed a great strain on the treatment units during the year. The situation has been further aggravated by the loss of approximately 10 acres of irrigation lagoons, previously used for the final treatment of filter effluent from the "Old" works, but now required as the site for new units under construction.

During the year it became necessary to renew the arms of six of the filter distributors. Owing to difficulties of supply of materials and in order to avoid a still further large reduction in treatment capacity, these distributors were taken out of commission, one by one, for repair. This work still further reduced the treatment capacity and automotically increased the overload on the remaining units. To meet these problems, and in an endeavor to maintain as high a degree of purification as possible under the circumstances, certain temporary works have been undertaken departmentally.

Erection of a line of 5-in. steel pipe (on elevated brick piers across the existing humus tanks and filters) from the effluent discharge point back to the tank effluent feed channel permits of recirculating the final effluent. An existing electric motor and pump have been adapted for pumping back the final effluent. The work was completed in less than 6 weeks, and recirculation has been in operation since January, 1950. Unfortunately, owing to high sewage flows, it has not as yet been found possible to operate this method continuously, but even with an average recirculation period of 8 hr. per day there is already a noticeable improvement in the conditions of the filter beds and effluent discharge.

Greatly increased volumes of sewage liquor have been disposed of on the farm irrigation areas, necessitating very careful attention to irrigation routine and some adjustment in the cropping program. Further work is being carried out to provide still greater capacity for sewage liquor on the farm irrigation areas.

The increasing popularity and use for domestic purposes of synthetic detergents has, during the latter part of the year, had a marked effect on existing treatment processes. There is a marked reduction in the amount of solid matter retained in the sedimentation tanks, a noticeable increase in the

* For last previous extract see This Journal, **22**, 2, 256 (Feb., 1950).

loading of filters, and a persistent foaming on the surface of the final effluent.

In spite of the foregoing difficulties, the normal treatment routine has been maintained at a reasonable degree of efficiency and a reasonably well purified effluent has been produced.

The average purification obtained throughout the year has been 84.10 per cent, a result slightly below that achieved in 1948–49 (85.93 per cent).

By rigid control of the treatment units (through the laboratory) and by careful attention to plant maintenance, it is hoped that effluents of reasonable quality can be maintained, so that the reduction in purification is not comparable with the marked increase in the volume of sewage received for treatment, until such times as the new works are completed and in operation.

Langley

The new spray jet filter, constructed at the Langley works last year, has now been in continuous operation for 12 months. After the initial problems of starting up and the period necessary for the maturing of the filter medium, markedly improved results have been obtained from the treatment processes.

As a further aid to improving conditions at the works a system of recirculation of part of the filter effluent has been incorporated into normal routine. This work was carried out to provide temporary increased treatment capacity, pending the closing down of the works on completion of extensions to the Cippenham plant, when the sewage at present draining to the Langley works will be brought to the main works for treatment. That this scheme has proved successful is beyond question when the significant increase in the percentage purification is noted and it is borne in mind that the volume and strength of the sewage has increased during the year.

This year the average percentage purification is shown to be 84.16 per cent, whereas before the new filter was operating the purification achieved was only 73.22 per cent.

An attempt will be made during the coming year to still further improve the treatment at these works by the provision of a humus tank for final settlement of the filter effluent. It is anticipated that this will afford considerable relief to the heavily overloaded irrigation areas by allowing a direct discharge of filter effluent, after passing through the humus tank, to the stream.

Laboratory

A large volume of work continues to be carried out in the laboratory. The nature of the work is becoming increasingly important in view of existing treatment difficulties and the steady development of industry in the town.

An alteration was made during the year in the method of obtaining samples for routine control purposes. Previously, individual samples were obtained at a certain time on most days of the week. In order to obtain a more comprehensive series of samples a method of composite sampling has been instituted. In this way, a fair average covering the entire 24 hr. is obtained in one sample. The method has resulted in slightly fewer samples being passed through the laboratory, but has permitted more detailed work to be carried out.

Work in the laboratory is covering a much wider range than heretofore, an example being the development of laboratory control for the operation of the grass drying plant now working on the farm at Dorney.

Special attention has again been directed toward obtaining information which will be of material assistance in operating the new works now under construction.

The increasing use of synthetic detergents in the home and in industry

is creating new problems at the sewage works. Through the laboratory, close attention is being given to the problem, and a careful scrutiny of all published literature, scientific discussions, and research work is creating a big task at the present time.

Prolonged experimental work, conducted through the laboratory, has resulted in the solution of a very difficult trade waste effluent problem. A scheme of pretreatment has been installed at the factory and the discharge, after treatment, is reaching the sewers in a reasonably satisfactory condition.

Experimental work in connection with the recirculation of filter effluent has now been put into full-scale practice. A development of this work has necessitated an investigation into the suitability of the existing Greiss-Ilosvay method for nitrite determination. Similar difficulties have been experienced with the oxidized nitrogen radicals present in trade waste effluents.

An important addition to the equipment of the laboratory is the acquisition of a Spekker absorptiometer. Work is now proceeding with the construction of a number of calibration curves for a variety of colorimetric tests on routine samples and, in particular, metals and toxic substances in trade waste effluents.

Extensions to the existing laboratory and offices are well in hand. It is anticipated that increased laboratory facilities will enable much valuable preliminary work to be carried out in connection with the starting up of the new treatment units. In addition, the extended premises as a whole should provide accommodation for the efficient administration of the department in the future.

Trade Waste Effluents

The work of trade waste effluent inspection and control has been well maintained during the past year; 821 inspections have been made and 283 samples obtained for examination in the laboratory. As an indication of the steady expansion of the work of this section of the department, 20 factories were surveyed for the first time during the year, making a total of 162 factories now under regular surveillance.

The volume of trade waste effluents reaching the works is estimated to be 475,000 g.p.d. (Imp.).

A review of the year's work shows that the firms are becoming more co-operative with regard to their responsibilities concerning the discharge of trade waste effluents. As a result it has been possible in several instances, to reduce the number of routine inspections without in any way jeopardizing the position governing the control of waste liquor discharges. This situation is leading to the realization of one of the chief objects involved when the organization for control and inspection was originally commenced.

The results obtained from analysis of industrial waste samples, when compared with previous years, indicate that another object of the work is being achieved; namely, the steady reduction in the strength of certain waste liquors as discharged to the sewers after pretreatment. The many pretreatment units now installed at factories are working in a very satisfactory manner and are helping materially to achieve an equalization in the trade waste effluent discharges.

Closer cooperation with the gas works has led to a further reduction in upset to treatment processes at the sewage works and it is hoped to obtain still further improvements in the pretreatment of gas liquor during the coming year.

Manor Farm

The very dry summer resulted in somewhat reduced crop yields from the rotational cropping work carried out in conjunction with sewage and sludge disposal. The grassland areas,

however, were maintained in reasonable condition with the assistance of controlled irrigation, the result being that the cattle fattened well on the grass and a useful tonage of dried grass was produced.

The total income from farm sales and sludge realized £ 2,004, this being £ 238 more than for the previous year.

The initial moisture content of fresh cut Italian rye grass brought in for drying averaged 80.37 per cent. This was reduced to 6.39 per cent by drying. As an experiment, drying for other farmers was undertaken. This work was carried out to the satisfaction of the farmers concerned and without interference in the routine work of the department. It is hoped to extend this class of work during the coming season. Also, in addition to baled hay, grass meal will be produced this year.

It is, however, as a unit of sewage disposal that the farm performs its most important function. The steadily increasing volumes of sewage reaching the works for treatment would have created an impossible situation had the farm land not been available, in good condition, to take a major proportion of the extra sewage flow. Since 1941, when actual farming operations were undertaken by the Council, the chief object of this work was to reclaim large areas of sewage sick land. Through the intervening years this policy has been steadily pursued, and as the sewage flows increased, additional volumes of sewage were by-passed to the land irrigation areas, where they have been disposed of without nuisance.

On completion of the extended land reclamation now going on, it is anticipated that the overload on the main works will be reduced to such an extent that, combined with the recirculation scheme already completed, there will be a pronounced improvement in the quality of the final effluent discharging from the main works.

TABLE I.—Summary of 1949–50 Operating Data, Cippenham Sewage Plant, Slough, England

Item	Average
Area of Borough (acres)	6,276
Population (estimated)	66,030
Rainfall (in.)	21.23
Average sewage flow (m.g.d. Imp.)	2.10
Per cent overload on treatment works	40.0
Total number of samples examined	1,037
Individual estimates	7,064
pH:	
Raw sewage	7.0
Settled sewage	7.1
Humus tank effluent	7.1
Oxygen absorbed (4 hr., N/80 $KMnO_4$, lab. temp.) (p.p.m.):	
Raw sewage	142.2
Settled sewage	115.5
Humus tank effluent	22.6
Nitrogen (NH_3) (p.p.m.):	
Raw sewage	58.7
Settled sewage	69.5
Humus tank effluent	29.4
Nitrogen (NO_3) (p.p.m.):	
Humus tank effluent	18.7
Suspended solids (p.p.m.):	
Raw sewage	417
Settled sewage	189
Humus tank effluent	61
B.O.D. (5-day at 18.3° C.) (p.p.m.):	
Raw sewage	672
Settled sewage	433
Humus tank effluent	30.7

Most of the sludge produced at various stages of treatment has been disposed of on the farm land after a period of digestion. The detritus and screenings were tipped, dried and sold as sludge. The sludge drying beds were in use throughout the summer. Dry sludge sold during the year amounted to 1,741 cu. yd., realizing £ 88.

A summary of operation data for the Cippenham works for the year April 1949–March 1950 is given in Table I.

EFFECTS OF INDUSTRIAL WASTES ON MUNICIPAL SEWAGE WORKS*

By E. F. Eldridge

Director and Chief Engineer, Washington Pollution Control Commission, Olympia, Wash.

Many, and no doubt a majority of industrial plants, are located in towns and cities and have access to the municipal sewer systems. On the other hand, it is equally true that industries having large volumes of strong wastes usually do not use the municipal system for disposal, except in the very large cities. This last statement includes such plants as pulp and paper mills, beet sugar plants, automobile manufacturing plants, etc.

In the larger cities the presence of industrial wastes influences to some extent the design and operation of sewer systems and treatment plants, and makes necessary ordinances to control these wastes. However, the real troubles arise in the smaller municipalities where the industrial wastes take on a predominating role. An almost impossible situation exists in too many instances where the industrial load entirely overshadows the domestic load.

Operator's Responsibility

Operators of municipal treatment plants and those having charge of the maintenance of sewer systems must become thoroughly acquainted with the industries connected to the system and with the nature, volume, and concentration of the wastes from these industries. Control of these wastes is absolutely necessary for protection of the system and proper operation of the treatment plant. The operator should have a general knowledge of the industrial processes; he should know what control can be reasonably expected of the industry, and should see that his city or town has proper ordinances, constantly enforced, to assure this control. An operator may think that this is beyond his duties and should be a function of the municipal officials. Actually, he may need to work through his superiors, but it is his job to operate his plant or maintain his system in the best possible manner. To do so he must of necessity take a leading interest in any factors affecting this operation. He is in a better position to determine these factors and the steps necessary to correct them than are other members of the local government.

Wastes Effects

In order to understand the effects of industrial wastes on sewer systems and treatment plants, it is first necessary to understand the wastes and the processes from which they come. Industrial wastes as they effect a sewage system may be divided into several groups, namely:

1. Those affecting the volumetric load or flow.
2. Those which deposit materials that interfere with flow or with such operations as pumping, measurement, etc.
3. Those which have a destructive action on the structures and equipment in the system or plant.
4. Those which increase the solids load on primary treatment units.
5. Those which increase the organic or B.O.D. load on both primary and secondary units.
6. Those which have a toxic or inhibiting effect on the various biological processes within the plant.

Perhaps the best way to discuss these effects is to take up each one of the

* Presented at 1950 Annual Meeting, Pacific Northwest Sewage Works Assn.; Tacoma, Wash.; May 10, 1950.

TABLE I.—Pacific Northwest Industries with Significant Wastes

Industry	Range of Population Equivalents
Dairy, creamery, and milk bottling	800 to 1,000
Condensery or dry milk	1,500 to 2,000
Cheese factory	2,000 to 3,000
Vegetable cannery—peas, corn, etc.	2,000 to 8,000
Fruit cannery—apples, pears, berries, etc.	——
Dehydration—potatoes, apples, etc.	——
Fish—salmon, tuna, etc.	——
Shellfish—oysters, clams, crabs, etc.	——
Slaughterhouses	500 to 3,500
Meat packing—including slaughtering	700 to 4,500
Paper mills—not including pulping	4,000 to 5,000
Pulp mills—sulfite, including liquor	120,000 to 1,300,000
Pulp mills—kraft, soda, etc.	45,000 to 100,000
Tanneries	18,000 to 20,000
Beet sugar factories—no Steffens	65,000 to 85,000
Beet sugar factories—with Steffens	115,000 to 135,000
Cotton textiles	2,500 to 6,000
Silk textiles	15,000 to 22,000
Breweries	——
Distilleries—grain	3,500 - up
Mines—gold, silver, and other metals	——
Mines—coal	——
Smelters	——
Gravel washings	——
Saw mills	——
Metal plating	——
Metal fabrication	——

groups, pointing out some of the industries having wastes showing these effects, together with the methods of control. First, however, a list (Table I) of major industries in the Pacific Northwest with significant waste discharges and showing the range of population equivalents of wastes containing organic constituents, is of interest. It should be understood that the population equivalents are based on the B.O.D. of the waste as compared to domestic sewage, and is only one of the undesirable characteristics of wastes. Other undesirable characteristics will be indicated as this discussion progresses. The values given in Table I are for the average plant and will, of course, vary widely; therefore, they are normally used only as guides.

Wastes Affecting Flow

A number of industries using municipal systems in the State of Washington use large quantities of water for process and wash waters. Vegetable and fruit canneries, especially those of Eastern Washington, are major industries in this group. The canneries are seasonal in their operations, making it necessary to design the sewers and treatment plant for large flows occurring only during a short season. Because of the excessive cost of providing for these temporary high flows, there is a tendency for the designing engineer to skimp on the sizes required. This results in an overloading of the system and plant and usually occurs during the portion of the year when stream conditions are most critical. During the remainder of the year inadequate flows interfere with proper cleaning of the sewer system and may be responsible for septic conditions in primary units.

Most of the seasonal industries, and especially the canneries, have occasion to use large volumes of water for cool-

ing and other purposes wherein they do not become contaminated with waste materials. One of the most effective methods of controlling the volumetric loading of a sewage system is by the segregation of these clean waters for separate discharge direct to watercourses or storm drains. This should be an item in every municipal ordinance for the protection of the sewage system.

Wastes Interfering with Flow

Numerous materials contained in industrial wastes may cause interference with flow, cause clogging of pumps, fill up grit chambers, clog bar screens, and otherwise interfere with sewer system and treatment plant operations. Some of the more common materials of this nature are manure and fleshings from meat packing plants. This material not only lodges in sewer lines, but also floats on the surface of settling tanks, increasing scum troubles and adding an undue load to digesters. Grease from meat packing plants is also troublesome, as it forms in balls, plugs sewers and pumps, adds to the scum in tanks and digesters, and may pass through two secondary units, where it gathers on the filter media. Municipal ordinances should require the dry cleaning of bins and killing floors in packing plants and slaughterhouses, and the disposal of the manure thus collected by hauling or spreading on land. All meat packing plants should be required to install and properly operate efficient grease traps.

Sand in large and excessive amounts is undesirable in a sewage system. Wastes from canneries (washing certain products), potato dehydration plants, beet sugar plants, and other industries may contain excessive quantities of sand. Some treatment plants either have no grit removal facilities, or those available may be inadequate to handle the excessive amounts, in which case the grit passes into sedimentation units and digesters, from which it is removed with difficulty. In case this problem becomes too troublesome, the offending industry should be required to install grit removal facilities.

Oil is undesirable in treatment plants; ordinances should provide that it be otherwise disposed of, except in cases where loss of oil is unavoidable (such as that contained in normal wash-down operations). Factories using large amounts of cutting oils should recover these oils. In certain eastern factories oil spilled on floors is mopped up with a detergent, collected in drums, and recovered as a normal operation.

Wastes Destructive to Structures

Acids, and sometimes alkalies, are especially destructive to sewer systems. Sulfuric acid used as pickling liquors in steel and other metal manufacturing plants may contain from 5 to 10 per cent acid. This acid must not be allowed in a sewer system without previous neutralization. Hydrochloric and nitric acids are used in metal-plating operations and likewise should be neutralized or diluted to such an extent as to come within a pH range of 5.5 to 9.5. If sewer protection is the only objective, the range may be extended somewhat.

Several months ago Seattle reported a condition of sewer destruction resulting from a waste containing sulfur dioxide from carbide manufacture. Certain pulp mill wastes are acid. Even whey from cheese manufacture has an acidity destructive to concrete. Neutralization is usually required in case of acid discharge. It may be of interest to note that the acid pickling liquor from steel cleaning operations contains sufficient ferrous sulfate to be of value as a sewage or water coagulation agent, if used in correct amounts and with lime for floc formation and neutralization.

Wastes Increasing Solids Load

A large number of industrial wastes contain excessive amounts of sus-

pended materials, which add to treatment plant operation difficulties. Some of the more common in Washington are vegetable and fruit canneries, fish and shellfish canneries, meat packing plants, and tanneries.

When a treatment plant is designed to include an industrial waste, such as that from a vegetable cannery, the basis for design does not normally include the disposal of unused parts of the product, seeds, skins, etc. Handling this material would necessitate extremely large digesters. Also, in many cases, grinding equipment, such as employed when garbage is disposed of in the treatment plant, would be required. The latter type of equipment is included in a very few large city treatment plants, but is not employed extensively. In the case of cannery wastes, therefore, treatment plants are usually not capable of handling this material. As a result, ordinances must require the installation of adequate (at least 20-mesh) and effective screens for all wastes before discharge to the sewer.

In several cases it has been suggested, by those not acquainted with plant operation, that canneries be allowed to grind all of the discarded products and discharge the grindings to the treatment plant by way of the sewers. This would certainly be a desirable operation from the standpoint of the cannery, but would act to the detriment of the plant. It not only would result in an overload on sedimentation units and digesters, but also would greatly increase the load to secondary units and add to the pollution caused by the discharge of the effluent.

Fish and shellfish canneries should be required to collect all offal. This material can be sold or given to reduction plants when such plants are available within a reasonable distance. In this connection, the Washington Pollution Control Commission has in many cases, such as in the Grays Harbor area, arranged with rendering plants for continuous collection of offal from fish canneries and has thereby reduced the pollution problem.

The matter of manure and fleshings collection in meat packing plants and slaughterhouses has already been discussed. This is a common source of excessive solids in treatment plants. Tanneries, unless very small, are in a class with pulp and paper mills and beet sugar plants, in that the wastes from such operations cannot be economically disposed of by discharge to a municipal sewer system.

Wastes Increasing B.O.D. Load

All organic industrial wastes contribute to the B.O.D. load if discharged to the treatment plant. The population equivalents shown for average plants (Table I) are based on the normal losses expected from the various types of plants. In other words, in preparing the population equivalents it was assumed that all waste prevention measures economically and practically possible were to be used by the industry, and that the waste as discharged had been reduced in organic concentration as much as possible by these measures. The facts, however, are that most industries do not practice waste prevention unless forced to do so either by the pollution control agencies, or by the town or city on whose sewer system they are located. Hence, without such control, industrial wastes may be many times the B.O.D. or population equivalent indicated by Table I. It is safe to assume that consulting engineers, when designing a plant to accommodate an industrial waste, will use as basic design data values obtained from tables such as this. The result is a condition of overload even as the new plant starts operations. This is no criticism of the engineer, because he is perfectly right in using these values and in assuming that the industry will use all practical prevention measures as its contribution to the treatment problem. This

assumption, as previously indicated, is seldom realized without enforced regulations on the part of the Pollution Control Commission or the municipality. Ordinances and regulations requiring waste prevention within the industry may be effective, but it has been found that it is more effective to require the industry to pay for treatment and sewer service on the basis of the waste load contributed. Under such conditions industry will voluntarily reduce losses. In several eastern cities, such methods resulted in 60 to 70 per cent reductions in the B.O.D. load, as well as substantial reductions in flow.

Although many of the waste prevention measures have been enumerated previously, they are repeated here for emphasis. Meat packing and slaughterhouses should provide for collection of blood, manure, and fleshings, and should provide and properly maintain grease traps. Canneries should provide adequate and tight 20-mesh screens. Fish canneries should provide for collection of offal. Milk plants should provide drip collectors on can washers, electronic level alarms to prevent overflow of tanks and vats, and temperature controls on equipment. They should discharge to the sewers no whey, skim milk, buttermilk, or spoiled milk.

The Washington Pollution Control Commission has prepared a long list of items by which waste prevention can be accomplished in milk plants. Similar lists are being prepared for all other industries as an aid to the reduction of pollution caused by wastes from industry or to reduce the load on municipal treatment plants.

The effects of an overload of B.O.D. on treatment plant operation is certainly apparent to everyone and need not be enumerated here. Many plants, especially in Eastern Washington, are experiencing these difficulties, and the Pollution Control Commission is doing all it can to help correct the situations and to advise the towns and cities on effective ordinances. Waste prevention is not expensive; it is not asking too much of industry to use care in its waste problem.

Wastes with Toxic and Inhibiting Effects

Some wastes discharged to sewer systems may have toxic effects on the biological organisms active in digesters and secondary units. These toxic effects either destroy activity entirely, or inhibit it to the detriment of plant efficiency and the plant effluent.

Some of the more common waste materials having toxic effects are: the metal ions (copper, chromium, and nickel) and cyanides from metal-plating operations; phenols and cresols from gas plants or oil refineries; chlorine; sulfur dioxide; acids and alkalies; oils; etc.

Usually, the main effect is on secondary units, as the substances are normally soluble in the sewage and pass through the primary tanks. In many cases, dilution is sufficient to reduce the concentration below the toxicity threshold and complete destruction of organisms is not often a result. However, there is a considerable difference between the amount necessary to completely kill the organisms and that which will inhibit and slow down the activity. The latter often occurs and may escape the attention of the operator. Low efficiency is usually the result of unfavorable environment for the organisms and may be the result of toxic conditions caused by overload or by a toxic substance in the sewage.

Certain metals affect digester activity, as they are precipitated by the alkalinity of the sewage and removed to the digester in the sludge. Copper is especially troublesome from this standpoint. In one case in the East, a digester was found to be completely dead due to the accumulation of copper from a plating concern.

The ordinance in this case must require that no toxic substances be discharged to the sewer system in such quantity as to affect the operation of the treatment plant.

Summary

The items suggested herein for correction of industrial waste effects on sewage systems may be summarized as follows:

1. Require segregation of all clean water, with separate discharge, if possible.
2. Require waste prevention measures in all industries (such as blood, manure, and grease collection in meat packing plants; screening of cannery waste; collection of offal from fish canneries; and no by-product or spoiled product dumping at milk plants).
3. In case of a grit problem, require grit removal at the industry.
4. Do not allow dumping of oil to the system.
5. Require neutralization of acids and alkalies to pH 5.5 to 9.5.
6. Do not allow the discharge of toxic materials, such as metal ions, cyanides, phenols, etc., to the sewers in destructive or inhibiting amounts.

CENTRAL STATES SEWAGE WORKS ASSOCIATION

1950 OPERATORS' BREAKFAST FORUM *

M. L. Robins and W. W. Mathews, *Co-Chairmen*

Respectively, Second Vice-President, C.S.S.W.A., and Chemist, Minneapolis-St. Paul Sanitary District, Minneapolis, Minn.; and Third Vice-President, C.S.S.W.A., and Superintendent, Gary Sanitary District, Gary, Ind.

Lime Water Softening Sludge

P. L. Brunner, Superintendent, Fort Wayne (Ind.) Sewage Treatment Plant: With the focusing of attention during the last two or three years on the use of lime water softening sludge in sewage treatment, it was decided to try some in the Fort Wayne plant in an effort to get better settling and improved effluent equality. This type of sludge was available from the local water treatment plant in considerably more than sufficient quantity for our purposes. In addition, disposal of the lime sludge was an added expense for the water utility. If it could be used in the sewage treatment process to advantage, it might be possible to effect a worthwhile saving for both parties concerned.

At first, the lime slurry was added at a ratio of 10 tons of lime solids to 10 tons of dry sewage solids. The resultant primary sludge was added directly to the digester as previously. However, the digester heating coils soon became coated with a solid scale about ¼- to ½-in. thick and having the general appearance of honeycombed concrete. The scale proved to be an excellent insulating medium, effectively preventing heat transfer from the coils to the digester contents. In addition, the heavily limed sludge settled on the digester bottoms at a rather steep angle of repose (about 30 deg.) and finally buried the heating coils completely. Removal of the bottom deposit and scale on the coils proved a long and tedious job.

As a result of this experience a considerably reduced lime addition was tried later to control sludge bulking. Lime sludge (25 per cent concentra-

* Exerpts as reported during the Operators' Breakfast, Twenty-Third Annual Convention, Central States Sewage Works Assn.; Indianapolis, Ind.; June 9–10, 1950.

tion) was added to the sewage at the rate of 2 to 3 tons of dry solids per day for a period of about 2 weeks, apparently with satisfactory results.

C. C. Larson, Chemist, Springfield (Ill.) Sanitary District: Attempts to discharge lime water softening sludge to the Springfield Sanitary District's sewers, with the same idea in mind of aiding sewage treatment processes, have had only one result—clogging of the sewers.

D. P. Backmeyer, Superintendent, Sewage Treatment and Garbage Disposal Plant, Marion, Ind.: Can the lime sludge be pumped through a force main? If so, what is the limiting concentration?

J. D. Walker, President, Walker Process Equipment, Inc., Aurora, Ill.: I know of one case where a 25 per cent slurry of lime softening wastes is being pumped through a 5-mi. force main at a velocity of 6.5 ft. per sec. without undue maintenance problems.

G. F. Bernauer, Sanitary Engineer, State Board of Health, Madison, Wis.: How did the lime addition affect settling and B.O.D. removals in the primary tanks?

Mr. Brunner: Much better settling was achieved in the primary tanks. Although tests were not run to prove the point, B.O.D. removals obviously were increased also. As regards flow problems in the sewers, the lime sludge at Fort Wayne was discharged through a short sewer to the interceptor, where a velocity of 2 ft. per sec. is normally maintained. Addition of the lime slurry at the 25 per cent ratio raised the dry solids in the digested sludge from the normal 3 per cent concentration to 5 per cent.

J. A. Drake, Sanitary Engineer, State Board of Health, Minneapolis, Minn.: How does the heavy lime addition affect the quality of gas produced in the digester?

Mr. Brunner: There is a slight increase in the carbon dioxide content.

Mr. Walker: There is a good probability that lime high in magnesium content may prove detrimental to the various sewage treatment processes. The chemical makeup of the lime would be important.

K. L. Mick, Superintendent and Chief Engineer, Minneapolis-St. Paul (Minn.) Sanitary District: The Minneapolis-St. Paul plant tried this same type of softening sludge use, but found that the flow to be handled resulted in an additional 40 tons of solids daily. It would appear to be economically wasteful to remove the lime softening sludge twice—once at the water plant and again at the sewage plant. Incidentally, incineration of sewage sludge containing the high lime content precipitated in the primary tanks gives a sticky mess reminding one of childhood taffy-pulling days.

G. W. Martin, Superintendent, Sewage Treatment Plant, Green Bay, Wis.: From the discussion given and previous reports on this same type of work, it would appear that use of lime water softening sludge as a coagulant may be beneficial in primary treatment plants. Nevertheless, the detrimental effects observed in digesters, along with the additional solids quantities to be ultimately disposed of, may make it economically unfeasible.

Frothing of Aerators

Mr. Brunner: In company with many other plants having troubles in this direction, the Fort Wayne plant has been bothered with frothing in the aerators. The trouble appears to be due to the increasing use of synthetic detergents in both homes and industry. At Fort Wayne, however, we have found a simple but effective means of keeping the froth from forming. This is by the addition of 1 p.p.m. of kerosene, gasoline, or old crankcase oil directly to the liquid surface in the aerator. The method is truly a case of "pouring oil on troubled waters!"

L. S. Kraus, Chemist, Peoria (Ill.)

Sanitary District: In the cases of frothing so far reported with sufficient data for analyzing the problem there are indications that the amount of froth produced is about inversely proportional to the amount of solids in the aeration liquor. Solids concentrations of from 3,000 to 5,000 p.p.m. seem to be best in preventing froth formation.

Mr. Mathews: Simply stopping the flow through an aeration tank while continuing air application will cause frothing. This would seem to bear out the low solids—high froth idea.

W. H. Wisely, Executive Secretary, FSWA: In thinking about the effects of detergents on treatment processes there are two things that seem to be basic—the characteristics of the detergents and their volume with respect to the sewage volume. As regards the characteristics, there are several chemical types, but the principal effect is physical—a lowering of liquid surface tension. It must be remembered, however, that there is a considerable difference between the common household detergents and those used in industry. Generally, the housewife does not feel that a detergent is doing its job unless there are plenty of suds; therefore, to please the customer, sudsing properties are "built in" the household cleansers. On the other hand, industrial detergent users usually do not mind the lack of suds, being interested in results rather than visual manifestation. This same difference of approach is noticeable with respect to the concentrations of detergents discharged to sewers. The American housewife, with an abundant supply available, is prone to use many times more detergent than is necessary to accomplish the task at hand. As a result, detergent "loadings" reaching the sewers are much greater than they should be.

It is interesting to compare the troubles voiced in regard to detergent content of sewage in this country with published comments concerning the problem in Great Britain. There, soap shortages have led to much wider use of detergents than in the United States and the effects on treatment plant operation are much more pronounced.

Paul W. Reed, Sanitary Engineer, U.S.P.H.S., Chicago, Ill.: Reduced organic loading of aeration tanks seems to increase the tendency for froth to form.

Mr. Kraus: We have found that high solids concentration and low air volume is an effective means of controlling frothing. In other words, it is possible to supply more air than is either necessary or good for best results, contrary to the general idea that an extreme excess of air is desirable—if you can pay for it. The cost of air supplied to an aeration tank is not a function of the tank solids content, but is instead a function of the sludge index and volume.

Mr. Walker: In putting mechanical aeration plants into operation we have found that the aeration tanks go through a "foaming" phase as the solids contents are increased. Further increase in the solids concentration in the tanks seems to eliminate the frothing. This transition phase has been almost universal in starting up small mechanical aeration units, and has been assumed to be part of the cycle in the development of good activated sludge.

Don E. Bloodgood, Professor of Sanitary Engineering, Purdue University: Aeration affects the surface tension of the mixed liquor and, presumably, the effect on surface tension caused by detergents, even in the initial passage through aeration tanks. This has been noticed in several instances where frothing has been much more pronounced at one end of a tank than at the other. Usually, in diffused air tanks frothing will be particularly bad at the inlet end, decreasing toward

the effluent end in ratio with the distance traveled.

Oscar Ward, Operator, Sewage Treatment Plant, Marshfield, Wis.: At Marshfield, 3 cu. ft. of air is used for every gallon of sewage. This is necessary because the B.O.D. of the raw sewage ranges from 500 to 700 p.p.m. The high oxygen requirement has never allowed us to think about the possibility that too much air is being used—we need that much for satisfactory B.O.D. removals.

Mr. Backmeyer: The detergents seem to keep the grease content of the sewage from either floating or settling out. The dispersal action reduces primary tank efficiencies considerably, putting greater loads on secondary treatment units. As a result, efficiencies of these units also suffer, with consequent deterioration of effluent quality.

H. P. Orland, Assistant Editor, Sewage and Industrial Wastes: In published reports on excessive aeration tank frothing, certain factors appear as common denominators. Perhaps the most striking of these is that in every instance there is a milk processing plant of one type or another tributary to the treatment plant. Although detergents are used elsewhere, it would seem that increased use of detergents in the clean-up functions of the milk processing industry is one of the prime causes of the frothing difficulty. Perhaps the butter fat and milk solids wasted to sewers in wash waters containing detergents combine in such a way as to form some resulting compound that is worse, from the frothing angle, than either of the components.

W. E. Ross, City Engineer, Richmond, Ind.: Changes in cutting oils at some of the local metal-working shops seemed to cause trouble at our plant. Presumably, the new oils incorporated detergents for both dispersal of the oil emulsion and cleaning of the metal. The combination of cutting oil emulsions and detergents is really something to work on!

J. A. Montgomery, President, Lakeside Engineering Corp., Chicago, Ill.: The frothing effect is not confined to aeration tanks alone; trickling filters are subject to the same "disease." In fact, frothing has been noticed in trickling filter drains since long befor detergents began to be widely used. One particular case is worthy of mention, however, as another possible clue to solution of the problem. In this instance, violent frothing occurred at the manhole where the filter effluent dropped from the drain collectors to a lower level for discharge. The filters at that time were handling a sewage with a fairly high mineral oil content. Segregation of the oil discharge from the filter effluent reduced the frothing action almost to the vanishing point.

M. W. Tatlock, Consulting Engineer, Dayton, Ohio: In one trickling filter plant treating molasses and yeast wastes, we have found that best results are obtained when the filters are actually giving off a frothy effluent.

TIPS AND QUIPS

The Worm's Turn

Instead of being ignominiously and unceremoniously dismissed from mind as unworthy of further attention, worms from the trickling filters at the Hays, Kans., sewage treatment plant have become sought after far and wide. In fact, so great has been the demand in recent months that Roy Binder, operator of the plant, has been forced to post a sign on the plant gate reading "After 5 P.M. and on Sundays worms will be $1 a bucket!"

Probably one of the most fantastic

true stories ever heard about sewage treatment, the worm episode at Hays has created quite a stir in places as far removed as the White Mountains of New Hampshire. Incidentally, there are indications of possible development of worm sales into a fairly lucrative by-product business. But let's start at the beginning.

The sewage treatment plant at Hays has a reputation as more of a show place than the water works. As a result of an excellent job of public relations, Operator Binder this spring had a chance to brag to a local reporter about his exceptional luck when fishing with worms from the trickling filter as bait.

The resulting publicity in the Hays *News* (under the headline "Best Fishing Worms in State Are Surplus Commodity Here") apparently made one of the national news service wires and was reprinted widely. In the first two weeks after the announcement 406 people visited the plant to get worms for bait. In addition, numerous out-of-state requests were received, most offering 50¢ per hundred with containers and transportation charges paid for by the purchaser. One, from New Hampshire, offered 75¢ per hundred for "all you can ship."

A later story in the *News* notes that the New York *Times* recently published the worm article, thereby bringing further inquiries about the fish worms—and greatly expanding the demand by residents within a 40-mile radius. On one recent Saturday morning 37 fishermen armed with buckets were at the gate before noon clamoring for some good fat worms to make their Sunday fishing excursions successful. After serving up buckets of 200 to 300 worms, free of charge, enough worms were left to fill an additional 100 orders.

What makes these worms so wonderful? By placing them on a hook and dangling them in water, Binder found that they live for 24 hr.; the native garden variety of fishworm lives only about 15 min. His explanation is as follows:

"These worms, you understand, are of a superior quality. They have lived all their lives in water and know their way around in it. The temperature of the water is not a shock to their sensitive nervous systems, as it is to the worms that have lived underground in warm temperatures all their lives. They have wiggled all their lives and they go right on wiggling, come wind, weather, catfish, or carp. They are real good worms and we give them away. What more would one want?" *

With fishworms lacking only neon lights on their tails for the ultimate in fish appeal reportedly free for the asking, and in reasonably unlimited quantities (they've never heard of birth control), the $1-per-bucket sign seems incongruous. However, there's good reason for it. Asked "How come?", Binder said:

"Had to do it to get some sleep and enough time to eat my meals. There is no business as flourishing as the worm business, particularly when they are served up free of charge in buckets of 200 to 300.

I had callers at 4 o'clock in the morning

* Editor's Note—The available literature on the biology of trickling filters reveals an amazing dearth of material concerning the types, life cycles, habits, and characteristics of the earthworms found therein. In fact, outside of the simple statement that "earthworms are often abundant in trickling filters and are easily distinguished from the other types by their larger size," the only information gained is that "two species frequently found are *Lumbricus rubellus* Hoff. and *Dendrobaena subricunda* (Eisen), with *Eisenia foetida* (Sav.), the common Brandling, also recorded."

Nevertheless, field observations by fishermen, plant operators, and invertebrate zoologists bring out some practical facts about the filter earthworms. Most important is that fish will push each other out of the way to get at one species, but will definitely shun the others. Distinguishing those that have fish appeal from those that do not is simple, however, as the fish-repulsive ones have distinctive buff-colored bands on every body segment. The less fancy worms (without bands) constitute the piscatorial tidbits.

and throughout the day until 11 o'clock at night practically all during the fishing season. There wasn't even time to eat my meals. I had to impose some restriction. I was being overworked and so were my worms!

I want it understood, however, that I wouldn't turn any fisherman down if he's pining for a quiet afternoon or evening at the fishing waters. I'm not that hard hearted. All I ask is a chance to eat and sleep!"

Maintenance "Timetable" for Centrifugal Pumps

Pumps give the best service when a preventive maintenance schedule is followed. The following schedule, published in a recent issue of *The Yoemans Guard*, pertains to the most severe applications and can be modified as necessary:

Every Year

Remove rotating element and inspect thoroughly for wear, ordering replacement parts if necessary. Check wearing ring clearances; generally, they should be approximately no more than 0.003 in. per inch on diameter of wearing rings.

Remove any deposit or scaling. Clean out water seal piping.

Measure total suction and discharge lifts as test of pipe conditions. (Record figures so they may be compared with figures of next test.)

Inspect foot valves and check valves, especially check valves which must safe-guard against water hammer when pump stops.

Every 6 Months

Replace packing with grade recommended by the manufacturer. Make sure seal cages are centered in stuffing boxes at the entrance of water seal piping.

Check shaft sleeves for scoring that would accelerate packing wear, ordering new sleeves if needed.

Check alignment of pump and motor, and shim up units as needed. (Check entire piping system if misalignment recurs frequently.) Unbolt piping at suction and discharge nozzles to see if it springs away—indicating strain on casing. Check all piping supports for soundness and effective support of load.

Every 3 Months

Drain lubricant, wash out oil wells and bearings with kerosene. In the case of sleeve bearings, check to see that oil rings are free to turn with the shaft. Repair or replace if defective. Refill with lubricant recommended by pump manufacturer.

Measure bearings for wear, replace if excessive. Generally, allow 0.002-in. clearance, plus 0.001-in. for each inch or fraction of an inch of shaft journal diameter.

Every Month

Check bearing temperature with thermometer—not by hand. If antifriction bearings are running hot, probably they have too much lubricant. If sleeve bearings are running too hot, probably they need more lubricant. Disassemble and inspect bearing if change in lubrication doesn't correct condition or, possibly the alignment of pump and motor should be checked.

Additional tips on avoiding common pump troubles, as well as little known facts about preventive maintenance, are also contained in a "Handbook for Care of Centrifugal Pumps," available on request, without charge, from Yeomans Brothers Co., 1431 North Dayton St., Chicago 22, Ill. Ask for "Manual 2000."

There'll Be Some Changes Made

In 1944, when Jamestown, N. Y., planned a new sewage treatment plant for postwar construction, no serious objection was voiced to the project and site selected. As a result, plans and specifications were prepared and held

in readiness awaiting an opportune time to build.

Two schemes were considered in the original proposal. The first was to utilize the existing Imhoff tank plant and add facilities for sludge digestion and secondary treatment; the second, for which plans were drawn, was to locate a new activated sludge plant on municipally-owned land in a highly industralized area of the city. Advantages claimed for the adopted scheme included elimination of 2.7 mi. of costly trunk sewer, a modern plant instead of a "hybrid" plant, ready accessibility for labor and supervision, and a lower original cost.

Review of the plans in April, 1950, to bring them up to date brought considerable opposition to the planned project. Despite the technical arguments available to refute all claims in opposition to the proposed plant, one opposition argument could not be overlooked. This was that industry was being stifled by not being permitted to acquire practically the last valuable industrial site within the city limits. As a result of further hearings the City Council voted to abandon the idea of a treatment plant at the site in question and at the same time voted to sell the property to a manufacturing concern.

The planning efforts for the activated sludge plant will have little value in the preparation of new plans for the trickling filter plant now contemplated for installation at the present site. The shift in attitude at Jamestown brings up the question of just how far ahead one can make detailed plans and still have them useable under altered circumstances when they are needed.

Industrial Wastes Recruiting

In the past, industrial wastes have been considered primarily as falling within the province of chemical engineers. As an example, however, of the all-around interest now being taken in the subject by university chemistry departments generally, D. Milne, chemical engineer, Production Engineering Section, General Motors Corp., calls attention to the following question asked on an examination in the course on "Physico-Chemical Methods in Analytical Chemistry" at Wayne University:

"A large cement tank was provided in the basement of the new Science Building to receive all wastes from the laboratories (acids, etc.) so that the liquid material could be neutralized before being discharged into the Detroit City sewers (City of Detroit Rules). Provision is made for discharging soda ash solution (Na_2CO_3) into this tank to neutralize excess acids. Make suitable drawings and explain how, with suitable electrodes, a potential measuring device, and other controls, the amount of Na_2CO_3 solution to keep the waste material at the discharge point at a pH of 7 ± 2 could be automatically controlled."

Inclusion of questions like this in the examinations, and discussions on the subject of waste treatment in the classroom, are expected by Mr. Milne to make many more future chemists and chemical engineers aware of an attractive new field of science. Operators should welcome this trend as a step in the right direction to encourage solution of their problems caused by industrial waste discharges.

Fume-Proof Paints

An estimated total damage of $200,000 occurring overnight to exterior house paints in Texas City, Tex., points to the same maintenance problem experienced in sewage treatment plants. The cause in both cases is hydrogen sulfide fumes, which react with lead pigments to form lead sulfide, a black compound.

The Texas City experience, reported in *Paint Progress*, **8**, 2, 11 (June, 1950), is a striking example of how fume-proof paints can withstand the

chemical attack of sulfide fumes. Homes covered with white paints containing lead pigments ranged in color from black to mottled shades of brown and gray. Some were affected on only one or two sides, indicating the unpredictability of the combination of atmospheric conditions and fumes producing the discoloration—conditions not always predictable even with well-managed fume control. Houses finished with paints based on zinc oxide, titanium dioxide, and selected inerts completely escaped the darkening effect.

Moral: Regardless of the color used, be sure that the base pigments of paints used around the treatment plant are fume-proof, particularly to hydrogen sulfide. A little time spent in checking may save considerable time and money in maintenance painting.

Slip of the Tip

It's peculiar how a simple movement of the finger tip can make one's face so red. In preparing copy for the July "Corner" one of the co-authors of "Effluent Trough Cleaning Device" (see page 940) was given as J. W. Spofford. Our apologies to J. W. Wofford, the actual co-author.

Thar's Gold in Them Thar Sewers

Every day, thousands of dollars worth of gold goes into the sewers along with the waste waters of the precious metals fabricating industry. According to S. Tour, consulting engineer, New York City, as reported in the March, 1950, issue of *Products Finishing*, this is a needless loss of gold and in many instances is the difference between profit and loss in manufacturing operations.

In the manufacture of rolled gold plate, watch cases, spectacle frames, high grade jewelry, dental gold inlays, gold dentures, costume jewelry, emblems, gold finished findings, and gold finished novelties, there are many pickling, polishing, tubbing, cleaning, and electroplating operations, followed by washing operations. Fine particles of gold in suspension and considerable gold in solution go down the drains with the waste waters and solutions from these operations.

In some plants the drains go to settling basins in an attempt to catch the gold in suspension. Only the heaviest particles are caught in this fashion, as the soap and cleaning agents in the waste waters prevent the finer particles from settling out. Only in a few instances, where expensive filtering equipment has been installed, are these finer particles caught. In most cases, they go down the sewer with the overflow from the settling basin. The value of the gold going into the sewer in this form may be as high as $1.00 per ton of waste water.

Only in connection with gold electroplating operations does the industry make an attempt to recover the gold that is in solution. In most cases, this recovery attempt is limited to a rinse in water to be re-used. In some cases, recovery is attempted by the use of "zinc boxes." Troughs or tanks are loaded with zinc shavings and the waste waters are percolated or allowed to flow through these boxes en route to the sewer. Ordinarily, such zinc boxes recover only 30 to 40 per cent of the gold in the waters and the balance goes down the sewer. Gold going to the sewer in this form may be as high as $3.00 per ton of waste water.

Don't get any wild ideas, however, about panning your sewers or inlet flumes, even if there is a precious metals plant in your town. Remember, the "high assay" mentioned is in solution or in such finely divided form that it won't settle out. In addition, by the time it's reached your sewage facilities it's been diluted many, many times. Sorry, no gold strike—but it's a nice feeling to know that the yellow stuff is there if you need it!

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Canadian Institute on Sewage and Sanitation	Bigwin Inn, Lake of Bay, Ont.	Sept. 11–13, 1950
West Virginia Sewage and Industrial Wastes Association	Hotel Pritchard, Huntington, W. Va.	Sept. 14–15, 1950
Iowa Sewage Works Association	Hotel Blackhawk, Davenport, Ia.	Sept. 19–21, 1950
Georgia Water and Sewage Association	Georgia Institute of Technology, Atlanta, Ga.	Sept. 20–22, 1950
Rocky Mountain Sewage Works Association	La Fonda Hotel, Santa Fe, N. Mex.	Sept. 27–29, 1950
South Dakota Water and Sewage Works Conference	Alonzo Ward Hotel, Aberdeen, S. Dak.	Sept. 28–29, 1950
Missouri Water and Sewerage Conference	Sheraton Hotel, St. Louis, Mo.	Oct. 1–3, 1950
North Dakota Water and Sewage Works Conference	Bismarck, N. Dak.	Oct. 4–6, 1950

Federation of Sewage Works Associations
Hotel Statler, Washington, D. C.
Oct. 9–12, 1950

Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Memphis, Tenn.	Oct. 23–25, 1950
North Carolina Sewage Works Association	Washington-Duke Hotel, Durham, N. C.	Nov. 13–15, 1950
Arizona Sewage and Water Works Association	Pioneer Hotel, Tucson, Ariz.	Nov. 30–Dec. 2, 1950

Editorials

SALES PROMOTION IN POLLUTION ABATEMENT

About two years ago the Pennsylvania Sanitary Water Board developed a small pamphlet entitled "Water is Wealth," in which the average citizen's responsibilities in the State's clean streams program were cleverly presented. Early this year the Oregon State Sanitary Authority began distribution of a 12-page illustrated booklet emphasizing the fact that stream pollution is "everybody's problem," and furnishing basic information for public assimilation. And now comes an attractively printed and illustrated brochure from the Georgia Department of Public Health entitled "Clean Streams in Georgia," through which the public in that state will learn about the problem and how to solve it.

This is excellent salesmanship—the kind of salesmanship that has been proved effective throughout the business world. It is also economical salesmanship, for it takes the place of innumerable personal and other contacts in which the same story must be told over and over. It is fundamental selling, because it is aimed at convincing the customer that the product is something he needs and wants, and not that he must buy—or else!

The enforcement provisions of pollution control laws are unquestionably essential to the effectiveness of such legislation. It is wrong, however, to use the punishment aspects of the law as the primary promotional element in the abatement campaign. Nothing will arouse resistance more quickly in the American citizen than the threat of the "big stick" before he is given the opportunity and information upon which to judge for himself the merits of a project requiring his approval. It is far better to bring about public acceptance and approval through honest education, leaving the enforcement provisions of the law as the remote heavy hand of doom that will be administered unequivocably but reluctantly as the unfortunate last resort.

Among the selling points that are stressed in the promotion literature used in Pennsylvania, Oregon, and Georgia are: public health hazards of stream pollution; economic losses; magnitude of the problem in the state; elementary discussion of treatment methods; treatment cost ranges; methods of financing; step-by-step procedure in the development of an abatement project; etc. Entirely nontechnical in composition and supplemented by diagrams, maps, and pictures, the presentation is made readable and interesting to all.

Newspaper and periodical releases are also used effectively by some stream pollution control authorities, the leader in this respect probably being the Ohio River Valley Water Sanitation Commission. By this means the public is kept continuously informed of policies, activities, and progress; and public consciousness of the stream pollution problem is created and maintained.

Call it propaganda, advertising, or what you will, there is nothing better than the printed word as a means of securing mass reaction in the human mind. A capable press agent, utilizing modern methods and equipped with the essential facts, can accomplish far more tangible results in a pollution abatement campaign than any amount

of legal brow-beating. It is also worthy of note that effective salesmanship builds good will; litigation destroys it!

Usually, the municipality or industry that is confronted with a pollution abatement problem receives its first official notice in the form of a technical report that is transmitted by a more or less curtly phrased letter making pointed reference to the law and demanding immediate action. The response is usually forthcoming through legal advisors, and the merry-go-round begins.

Suppose that the first notice was given the same careful preparation that is accorded an important sales letter in a business organization. In addition to the technical report it would transmit other literature showing that the pollution campaign was statewide and not discriminatory, and that clean streams were more than a bureaucratic ideal. It would offer full explanation of the local situation by a competent field representative, in addition to technical cooperation and guidance in the preliminary phase of project development. We are reminded of the fable in which the Sun was easily able to cause the traveler to remove his cloak after the North Wind had failed to do so by brute force.

Pollution control authorities in Pennsylvania, Oregon, and Georgia are to be commended for the philosophy on which they have chosen to base their pollution abatement campaigns. All similar governmental agencies will do well to follow this progressive pattern.

W. H. W.

CONVENTION NEWS ITEM

WASHINGTON, OCTOBER 9—High government authorities were stunned today as the Federation of Sewage and Industrial Wastes Associations moved through the first sessions of its Twenty-third Annual Meeting at the Hotel Statler. Frequent references during the technical program to such objectives as "waste prevention" and "waste control"—previously unheard of in Washington—were received with devastating consternation.

Speaking bluntly in a hurriedly arranged news conference, a spokesman who asked that his name be withheld stated, "Who are these upstarts that take it upon themselves to speak about wastes with such authority? It is axiomatic that wastes are purely a government prerogative not to be bandied about with such irreverent nonchalance by any handful of self-styled experts! The whole thing is preposterous, irrelevant, and immaterial!"

Treasury Department officials, however, while concerned, viewed the situation more calmly. One representative, also unidentified by request, observed that, "Fantastic though it may sound, we are more than a little intrigued by this idea of waste prevention and control. We have actually begun the development of a program—idealistic to be sure—but nevertheless applicable under conventional governmental policies. We have tentatively estimated that the program can be consummated at a cost of only $9 billion per year, which will involve but a 20 per cent increase in taxes."

Hotel Statler officials confirmed at a late hour that the FSWA annual meeting was proceeding according to plan, with committee meetings underway in all suites held by equipment company representatives. A record-breaking registration was reported.

W. H. W.

Federation Affairs

PREVIEW OF TWENTY-THIRD ANNUAL MEETING

Hotel Statler, Washington, D. C., October 9–12, 1950

*

In Conjunction With
The Maryland-Delaware Water and Sewerage Association
and
The Federal Sewage Research Association

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An exceptionally interesting and informative technical program of diverse and timely topics will make the Twenty-Third Annual Meeting a high-light event of the year for the Federation's membership. The many local arrangements, carefully worked out by Ralph E. Fuhrman and his host committee members of the Maryland-Delaware Water and Sewerage Association and the Federal Sewage Research Association, will complement the high technical quality of the work of the program committee by providing excellent social and entertainment features. In addition, an excellent opportunity for members and guests to see and discuss the latest developments in sewage and industrial waste works equipment and supplies will be afforded by the manufacturers' exhibit, always an important adjunct of Federation meetings.

Following the precedent established in 1948, the program will extend over four days in order to include all of the features planned for the Twenty-Third Annual Meeting.

THE PROGRAM

MONDAY, OCTOBER 9

Morning

Registration—Upper Lobby.

Inspection of Exhibits—Congressional Room, Federal Room, and Upper Capitol Terrace.

Twenty-Third Annual Meeting Called to Order
President A. H. Niles.

Welcome to District of Columbia
Brig. Gen. Gordon R. Young, Engineer Commissioner, District of Columbia.

Problems of Water Pollution Abatement in the United States
Mark D. Hollis, Assistant Surgeon General, U.S.P.H.S.

Afternoon

Measurement of Sewage Flows
Walter H. Brown, Jr., Engineer, Builders-Providence, Inc.
Discussion: A. A. Kalinske, Director of Development, Infilco, Inc.

Sewage Disposal at Tampa, Florida
Paul E. Langdon, Consulting Engineer.
Discussion: David B. Lee, Director, Bureau of Sanitary Engineering, Florida State Board of Health.

Preaeration and Air Flocculation
Frank C. Roe, Eastern Manager, Carborundum Co.
Discussion: Uhl T. Mann, Superintendent, Ley Creek Sewage Treatment Plant, Syracuse, N. Y.

Sewer Service Charge Practice
M. W. Tatlock, Consulting Engineer.
Discussion: F. M. Veatch, Consulting Engineer.

Evening

RECEPTION—ENTERTAINMENT—Presidential Ballroom.

TUESDAY, OCTOBER 10

Morning

Sewage Pumping Stations—How Should We Design Them?
Richard R. Kennedy, Consulting Engineer.
Discussion: Grant M. Olewiler, Superintendent of Sanitary Drainage, Lower Merion Township, Pa.

Recent Developments in Dual Disposal
Morris M. Cohn, Sanitary Engineer, Schenectady, N. Y., and Editor, *Sewage and Industrial Wastes Engineering.*
Discussion: B. A. Poole, Director, Bureau of Environmental Sanitation, Indiana State Board of Health.

A Simplified Method for the Analysis of B.O.D. Data
Edward A. Moore, Harold A. Thomas, Jr., and William B. Snow, respectively, Associate Professors of Sanitary Chemistry and Sanitary Engineering, Harvard University, and Associate Professor of Civil Engineering, Duke University.
Discussion: C. C. Ruehhoft, Cincinnati Environmental Health Center, U.S.P.H.S.

Noon

ANNUAL FEDERATION LUNCHEON—Presidential Ballroom.
Address: By a speaker of national reputation to be announced.

Afternoon

Performance of Gravity Type Oil-Water Separator in Petroleum Refinery Wastes
R. N. Giles, R. J. Austin, F. W. Scheineman, and C. T. Nicholson, Standard Oil Company of Indiana.
Discussion: Gerard A. Rohlich, Professor of Sanitary Engineering, University of Wisconsin.

Treatment and Disposal of Metal-Plating Wastes
Jack E. Cooper, Supervisor, Water and Waste Laboratory, Ford Motor Co.
Discussion: A. Kenneth Graham, Consulting Electrochemist and Engineer.

Survey of Industrial Wastes in the Lake Huron-Lake Erie Sector of the International Boundary Waters

Hayse H. Black, L. F. Oeming, and A. E. Berry, respectively, Sanitary Engineer, U.S.P.H.S.; Sanitary Engineer, Michigan Stream Control Commission; and Director, Sanitary Engineering Division, Ontario Department of Public Health.

Discussion: L. A. Danse, General Motors Corp., and A. D. McRae, Imperial Oil, Ltd.

WEDNESDAY, OCTOBER 11

Morning

Circulation of Water in Tidal Estuaries

Bostwick H. Ketchum, Woods Hole Oceanographic Institution.

Discussion: A. M. Rawn, Chief Engineer and General Manager, Los Angeles County Sanitation Districts.

Natural Reduction of Paper Mill Color

Milo A. Churchill, Sanitary Engineer, Tennessee Valley Authority.

Discussion: W. D. Hanlon, Research Fellow, Rutgers University.

Effect of Radioisotopes in Biological Oxidation of Organic Matter

W. N. Grune, T. Jaffe, A. Diachisin, and Rolf Eliassen, respectively, Research Associate, Department of Sanitary Engineering, New York University; Sanitary Chemist; and Professor of Sanitary Engineering, Massachusetts Institute of Technology.

Discussion: Arthur E. Gorman, Sanitary Engineer, U. S. Atomic Energy Commission.

Alternating Double Filtration at the Works of the Birmingham, Tame and Rea District Drainage Board

M. R. Vincent Daviss, Deputy Engineer, Birmingham, Tame and Rea District Drainage Board.

Discussion: E. Sherman Chase, Consulting Engineer.

Afternoon

Inspection Trip

District of Columbia Sewage Treatment Plant at Blue Plains, D. C.
Pentagon Building Drainage Treatment Plant, Arlington, Va.

Evening

ANNUAL FEDERATION DINNER AND DANCE—Presidential Ballroom.

THURSDAY, OCTOBER 12

Morning—Concurrent Sessions

Sewage Operators' Forum

C. C. Larson, Leader

Sampling Technic.

Gail P. Edwards.

Lubrication of Mechanical Equipment.

John W. Johnson.

Operation and Maintenance of Electrical Equipment.

H. V. Crawford.

Public Relations.
Walter A. Sperry.
Effect of Detergents on Sewage Treatment Plants.
Joseph A. McCarthy.

Industrial Wastes Forum

R. D. Hoak, Leader

Pretreatment for Recovery of Usable Products.
Stuart E. Coburn and T. R. Haseltine.
Treatment of Industrial Wastes with Domestic Sewage.
T. C. Schaetzle and S. I. Zack.
Pulp and Paper Mill Wastes.
Harry W. Gehm.
B.O.D. of Industrial Wastes.
Robert S. Ingols and H. D. Lyon.

TECHNICAL PROGRAM COMMENTS

As has proven so successful in previous Federation conventions, the technical program has been developed to cater to the exceedingly varied interests of the membership. Under the leadership of F. W. Gilcreas, the Program Committee has arranged for an excellent roster of diversified and timely papers, to be presented and discussed by acknowledged leaders in their fields. Topics to be covered range from basic problems in sewage and industrial wastes treatment to specialized problems of specific wastes and such items of general interest as sewer service charge practice and public relations.

An Industrial Wastes Forum, first introduced so successfully at the 1949 meeting, will run concurrently on Thursday morning with the perennially top-notch Operators' Forum. Subjects for both forum sessions have been carefully selected to provoke active and productive round-table discussions.

Worthwhile and informative material has been provided for those interested in each phase of the field, in keeping with the expanding outlook and interests of the Federation.

SOCIAL FUNCTIONS

An informal reception and entertainment on Monday evening will provide an excellent opportunity to get acquainted. A program of professional talent will provide the background for this prime opportunity to greet old friends and meet new ones.

The principal speaker at the Federation Luncheon on Tuesday will be someone of national or international reputation, who will discuss matters of interest to all. As usual, special tables will be reserved at the luncheon for the Quarter Century Operators' Club.

Always a favored event, the Annual Dinner and Dance on Wednesday evening will follow the successful pattern of previous years. The only business will be the presentation of awards—there will be no speeches—and probably selected "home-talent" entertainment. Dancing to an excellent orchestra will afford pleasurable entertainment for the remainder of the evening. Dress will be optional.

No entertainment is scheduled for Tuesday evening, allowing everyone the opportunity to dine and relax according to his own wishes. Washington boasts many fine dining places and a wide variety of entertainment, so the free evening should be an enjoyable one.

LADIES' ENTERTAINMENT

Special entertainment for the ladies will emphasize sight-seeing because of the numerous points of interest in and near Washington. All special events will be scheduled for the afternoons of the first three days, leaving mornings open for resting or shopping.

One tour will cover the U. S. Capitol Building, Library of Congress, Supreme Court, Smithsonian Institution, Folger Shakespeare Library, and the National Gallery of Art. Another feature will be a trip to Mt. Vernon, with stops en route at Alexandria, Arlington National Cemetery, and Arlington House.

The Ladies' Committee is also considering a fashion show, and optional trips to Annapolis, old Georgetown, and other famous places.

INSPECTION TRIP

Highlights of the inspection trip on Wednesday afternoon will be visits to the District of Columbia sewage treatment plant at Blue Plains and the sewage treatment plant at the Pentagon Building in Arlington, Va. Inspection of these modern sanitary facilities under the direction of well-informed guides should prove profitable and provide an enjoyable interlude in the meeting program.

EXHIBITS

Rivaling the technical program in interest and variety, the display of sewage works equipment and supplies planned for the Twenty-Third Annual Meeting will be outstanding. All available exhibit space is expected to be allocated by the Water and Sewage Works Manufacturers Association before the meeting. At least 29 manufacturers and suppliers will display their products, and informed company representatives will supplement the exhibits of improved and new equipment with first-hand technical data.

The following companies have already indicated their intentions of being represented in the exhibit:

American City Magazine
American Well Works
Builders-Providence, Inc.
Carter Company, Ralph B.
Chain Belt Company
Chicago Pump Company
Dorr Company, Inc.
Engineering News-Record
General Electric Company
Hardinge Company
Infilco, Inc.
Jeffrey Manufacturing Company
Johns-Manville Corp.
Lakeside Engineering Corp.
Limestone Products Corp.
Link-Belt Company
Lock Joint Pipe Company
Nichols Engineering and Research Corp.
Pacific Flush-Tank Company
Public Works Magazine
Sewage and Industrial Wastes Engineering

Simplex Valve & Meter Company
Stewart, Inc., W. H.
Walker Process Equipment, Inc.
Wallace & Tiernan Company, Inc.
Water & Sewage Works
Westinghouse Electric Corp.
Worthington Pump & Machinery Corp.
Yeomans Brothers Company

REGISTRATION INFORMATION

As tentatively established, a fee of $11.00 will cover registration, technical session privileges, the Monday Reception-Entertainment, and the Wednesday Dinner and Dance. Tickets for the Annual Federation Luncheon on Tuesday will be $3.50, and for the Wednesday Inspection Trip will be $1.25. Separate tickets for the various events will be: registration fee (required for attendance at the technical sessions) $5.00; Reception-Entertainment $1.00; and Dinner and Dance $6.00.

HOTEL ACCOMMODATIONS

Ample hotel accommodations have been arranged for Federation members and guests attending the Washington meeting. However, reservations must be made well in advance, as Washington is a crowded tourist city during the fall months, in addition to being the center of the Nation's activity when Congress is in session, and rooms allocated for those attending the Federation meeting will probably be released to the general public about September 25.

Requests for reservations should be sent directly to the Hotel Statler, headquarters hotel for the convention. A schedule of room rates is indicated on the reservation request card that has been sent to all Federation members.

LOCAL ARRANGEMENTS COMMITTEE

The Local Arrangements Committee, under the chairmanship of Ralph E. Fuhrman, is composed of the chairmen of the following sub-committees:

Registration Committee: W. McLean Bingley, chairman; Leonard B. Dworsky; G. E. McCallum; Donald L. Snow; and Paul D. McNamee.

Finance Committee: A. P. Rudder, chairman; James W. Feild; and Robert T. Regester.

Hotel Arrangements Committee: Col. M. J. Blew, chairman; Roy H. Ritter; Henry L. Roahrig; A. H. Neill; and Hugh A. Schreiber.

Inspection Trip Committee: Maurice H. Coblenz, chairman; C. E. Keefer; Albert L. Genter; William L. Torrey; John E. Rice; and Willard S. Sitler.

Local Host Committee: William H. Cary, Jr., chairman; Edwin R. Cotton; David Wood; Stanley E. Kappe; Harry B. Shaw; J. K. Hoskins; Frederick S. Kent; and Allan B. Fay.

Entertainment Committee: James W. Engle, chairman; L. E. McClung; and G. J. Requardt.

Ladies' Entertainment Committee: Mrs. Stanley E. Kappe, chairman; Mrs. William H. Cary, Jr.; Mrs. Roy H. Ritter; Mrs. Harry B. Shaw; Mrs. Paul D. McNamee; Mrs. Frederick S. Kent; Mrs. G. E. McCallum; Mrs. James W. Engle; Mrs. Ellwood Johnson; Mrs. Harold A. Kemp; Mrs. T. F. O'Connor; and Miss Virginia Rightor.

Reviews and Abstracts*

Treatment of Yeast Products Wastes. By M. W. Tatlock. *Proc.*, Third Industrial Waste Conference, pp. 111–123, Purdue University (1947).

An introductory discussion of yeast and yeast utilization in industry is followed by a report on the operation of "controlled digestion" type treatment plants for yeast manufacturing wastes. The features of the controlled digestion process are: digestion at 90° to 95° F., added ammonium salts if waste is deficient in nitrogen, sludge solids added for surface, active methane fermentation sludge added as seed, contents of digestion tank recirculated through heat exchanger for mixing and heating, and feed rate based on reduction of volatile acids. The plant design and operating procedures at the Standard Brands plant at Pekin, Ill., and the National Grain Yeast Corp. at Crystal Lake, Ill., are given. At the first plant, controlled digestion yields a 5-day B.O.D. reduction of 80 to 85 per cent and a 50 per cent reduction in volatile solids. At the second plant, 5-day B.O.D. reduction of about 90 per cent is reported, with reduction in total volatile solids of about 65 per cent.

Kenneth Rohde

What Do We Have Left After a Fermentation Process? By Nestor Bohonos. *Proc.*, Third Industrial Waste Conference, pp. 124–127, Purdue University (1947).

The nutritive requirements, growth, and the products of the metabolism of yeasts, bacteria, and molds are discussed. The products of the fermentation are determined by many factors, among them being the nature of the organism, the ingredients present in or absent from the media, physical conditions or treatment, and the product separation or isolation process.

Kenneth Rohde

Do Spent Hops and Spent Grain Press Liquor Have Value? By R. L. Hall. *Proc.*, Third Industrial Waste Conference, pp. 138–152, Purdue University (1947).

Although two of the wastes from the brewing industry (dried yeast and dried spent grains) find use as feeds, there is little use for the bulky spent hops and the high B.O.D. spent grain press liquors.

In consideration of the spent hops disposal problem, the common brewing process is examined critically and it is pointed out that the present brewing method results in only a partial utilization of the full flavor value of the hops. It is suggested that an efficient extraction, with organic solvent, of a comparatively small amount of hops would yield sufficient hop oil extract for flavor purposes. Further, the spent hops so extracted would not have the bitter flavor, which makes present spent hops objectionable for cattle feed.

In the case of the spent grain press liquors, inoculation with yeast and combined biological-aeration action, reduced the B.O.D. 73 per cent and the dissolved solids 67 per cent. It was felt that after sedimentation the supernatant from this process could be discharged to the sewers, yielding a much lower loading; the settled solids could be returned and processed with the spent grains into feed.

Kenneth Rohde

Wastes from a Whiskey Distillery—Sources and Characteristics. By C. W. Klassen and A. P. Troemper. *Proc.*, Third Industrial Waste Conference, pp. 153–164, Purdue University (1947).

A discussion of distillery practices as they effect the quantity and strength of the waste is presented. The tremendous importance of the production of cattle feed from the thick slop is illustrated by the

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

population equivalent (B.O.D. basis) for 1,000-bu. grind. The wastes for a typical bourbon formula yield a population equivalent of 35,810 if no feed is recovered and all of the slops are discharged. Where feed is recovered this population equivalent drops to 1,050. The various processes for the handling and drying of the slops for feed are discussed critically and the economic soundness of the program is emphasized, as the feeds sell for about four times the process cost.

KENNETH ROHDE

Disposal of Refinery Waste Water Containing Water-Soluble Sulfonates. BY HANS SCHINDLER. *Pet. Refiner*, **28**, 10, 153 (Oct., 1940).

A pilot plant is described that has been handling 850,000 gal. per month of refinery water containing sulfonated alkyl aromatic compounds. Effective treatment is accomplished by adjusting the water to pH 5 by adding acid or alkali; adding lime to pH 8 and settling. If decolorization and settling are poor in this step, the pH is raised to 10 and ferrous sulfate is added. The lime floc is a good adsorbent for oil and effectively removes it from the water. Optimum settling occurs at pH 8.4. The clear effluent is discharged at a uniform rate.

The refinery converts acid sludge in a plant which discharges a waste water containing 0.1 to 0.2 per cent H_2SO_4. It has been found that accumulating the sulfonate wastes and adding them to the constant stream of acid water in a 15:85 ratio and treating the blend with lime effects good color and sulfonate removal. Ferrous sulfate additions are required only when color is excessively high.

This plant has reduced color to 150 from 10,000 p.p.m.; oxygen consumed to 63 from 537 p.p.m.; and oil to 54 from 5,480 p.p.m. It is still regarded as an experimental operation, and studies are in progress to attain improved results.

RICHARD D. HOAK

Gaging and Sampling Water-Borne Industrial Wastes. BY C. F. HAUCK. *ASTM Bull. 162* (Dec., 1949).

A concise and instructive discussion by a well-qualified author. In collecting a representative sample these questions must be considered: "Is the sample intended to reflect average or spot conditions? Does the volume and composition of the waste water fluctuate widely or not? Are variations in composition periodic or random? Where in the waste-water flow route should the sample be obtained? Is the waste water homogeneous at the sampling point? How long should the sample lines be purged before the sample is taken? Is it necessary to preserve the sample and how can this be accomplished? How much sample will be needed to make the analyses desired?" These questions indicate the precautions that must be observed in good sampling practice, and the author gives sound advice on each.

The paper discusses manual *vs.* mechanical sampling; flow metering devices and locations for flow measurements; velocities for suspending various solids; and statistical analysis of data. Formulas for various flow meters are given, with an indication of their cost and range of accuracy. A useful tabulation of recommended preservatives is included for practically all of the laboratory tests likely to be made on a sample, together with time limits during which fixation is effective. Too concise for adequate abstracting, the paper is an excellent guide to sampling and gaging procedures.

RICHARD D. HOAK

Use of Bacteria Studied as Measure of Stream Pollution by Wastes. BY W. B. HART. *Pet. Processing*, **5**, 498 (May, 1950).

The value of biological surveys of streams as adjuncts to industrial waste disposal programs is being widely recognized. Such surveys not only describe current stream conditions, but also give an indication of past history and provide a measure of stream-recovery progress.

Although fish are the most spectacular of the living things in streams, the plankton and protozoa on which they feed, and the bacteria which are the food supply of these organisms, and which make the primary attack on pollutants, are equally important in stream ecology. In 1947 the American Petroleum Institute established a research project to determine whether bacteria could be used as indicators of industrial pollution.

This investigation indicated that bacteria cannot be used as pollution indicators. Samples were collected from 171 sources in Pennsylvania—11 from unpolluted, 42 from mildly polluted, and 118

from moderately to heavily polluted streams. Representative bacteria were selected from each sample and classified by genus. Physical and chemical tests were made on some of the samples for correlation. The bacteria found were predominately gram-negative rods, and 80 to 90 per cent were *Achromobacter*, *Flavobacterium*, *Alcaligenes*, and *Pseudomonas*. Surprisingly, these forms were as pronounced in number and variety in both polluted and unpolluted samples, and no single form was sufficiently significant to be regarded as a good test organism.

RICHARD D. HOAK

Phenol Recovery from Waste Ammonia Liquor. BY V. LOWENSTEIN, B. SCHNABEL, AND V. KEJLA. *Gaz, Woda i Tech. Sanit.* (Poland), **24**, 94 (Mar., 1950).

The authors examined numerous solvents in use at the present time in the recovery of phenols from waste ammonia liquors. Commercially available solvents, including many esters, ketones, alcohols, and ethers, were checked as substitutes for butyl octane and their effectiveness in extracting mono- and poly-hydroxyphenol was determined. Specific compounds, such as methyl-butyl ketone, methyl-iso butyl ketone, dibutyl ether, butyl and amyl octane, were found suitable for this purpose.

CONRAD P. STRAUB

Construction of a Haworth-Type Sewage Treatment Plant. BY TEODAT BIYK *Gaz, Woda i Tech. Sanit.* (Poland), **24**, 110 (Mar., 1950).

Reportedly the smallest activated sludge treatment plant of the Haworth type in Poland, this plant is to serve a sanitorium with a population of 650 patients and 280 auxilliary personnel. The plant is designed for an hourly flow of 0.222 cu. ft. per sec. and includes the following units: collecting well divided into two part portions, one 11.12 ft. by 11.12 ft. with a water depth of 6.25 ft., in which an inclined rack is placed (*Abstractor's note:* All dimensions given are approximate due to conversion from metric units), and the other, which serves as a sludge well, 11.12 ft. by 3.1 ft. by 6.25 ft.; equalizing tank 13.1 ft. by 9.83 ft. by 8.21 ft. deep located 13.1 ft. above the level of the collecting tank (the sewage is pumped to this unit and flows through the remainder of the plant by gravity); primary settling tank of 9.83-ft. diameter and 10.5-ft. side wall depth, with central feed and 8 spoke-like weirs feeding into a peripheral weir and a 1-hr. detention time; aeration tank, four channels, each approximately 4 ft. wide and 32.83 ft. long, with a water depth of 4.92 ft., first and third equipped with Haworth paddles, which rotate at 15 r.p.m.; secondary settling basin 9.83 ft. in diameter, total depth including sludge hopper 12.5 ft., detention time 30 min.; chlorination contact chamber to be used should chlorination become necessary; unheated digestion tank 12.5 ft. in diameter, total water depth 18 ft.; gas storage chamber (gas may be used for heating and lighting the plant and neighboring area); and sludge drying beds, total area 775 sq. ft. divided into three equal beds. With the exception of the sludge drying beds the entire plant is enclosed. Some of the difficulties encountered in operation are discussed and suggestions for improvement are offered.

CONRAD P. STRAUB

Report of the Metropolitan Water, Sewerage, and Drainage Board (Sydney, Australia) for the Year Ended June 30, 1949.

This report covers chiefly the water supply problems for a population of 1,800,000 and sewerage for a population of 1,282,991 (as of June 30, 1949). The Board operates 5 small sewage treatment plants serving 26,909 population, with flows varying from 45.3 to 66.1 g.c.p.d. (Imp.). The average water consumption was 73.5 g.c.p.d. (Imp.). The main discharge is through two outfalls to the sea. Construction of grit chambers and sedimentation tanks has begun on one outfall. Industrial wastes are being investigated.

LANGDON PEARSE

Melbourne and Metropolitan Board of Works, Report for Year Ended June 30, 1949.

This Board has been functioning since March 18, 1891. It manages a metropolitan water supply and main, and general sewerage and drainage. Statistics are given in a separate publication, the "Analyses of Accounts."

In 1948 the Board was authorized to control the admission of trade wastes into sewers. The additional charge therefor will be at the rate of 10 s. ($1.13) for each 10,000 Imp. gal. of waste, with a minimum charge

of £5 ($11.25) per annum. Where industries reduce their discharge rate, a discount is allowed of 2½ per cent for every 5 per cent by which the ratio of the maximum hourly discharge to the mean hourly discharge is less than four to one. However, in no case is the discount to exceed 30 per cent.

The by-laws permit relating the quantity of waste to the water supplied by the Board or obtained from other sources. Apparently there are about 1,000 industrial establishments affected.

The Metropolitan farm (24,950 acres) is still being operated for the purification and disposal of sewage, with grazing of cattle. For the year, the cost was £140,189 ($316,000), or about 2 shillings, 3 pence ($0.25) per capita. The revenue from the sale of cattle was £101,253 ($228,000). On June 30, 1949, there were 13,300 cattle on the farm. LANGDON PEARSE

Auckland Metropolitan Drainage Board—Annual Report and Statement of Accounts for the Year Ended March 31, 1949. 18 pp. mimeo.

This is a Board with 15 members elected triennially by the Councils of 11 constituent authorities within the inner area of the District. The 1948 population was 249,900 on an area of 60.5 sq. mi. The Board operates and maintains a main sewerage system and certain minor sewers or drains. The annual tax for 1950 was £78,040 (approximately $218,500); bonds are outstanding in the amount of £469,151.

The Board succeeded the older Auckland and Suburban Drainage Board in 1945. The present main sewer discharges through the Orakei disposal works (grit chamber, screens, three storage tanks) into Waitemata Harbor. The three storage tanks are out of service, so the discharge cannot be limited to the ebb tides.

The existing main sewer was designed on a basis of 210 Imp. (252 U.S.) g.p.d., or six times the average rate of water use (35 Imp. g.p.d.), without allowance for industrial wastes. The water use has risen to 50 Imp. g.p.d. The sewer is surcharged at time of storm. The problem is under study.

In Dec., 1948, the chief engineer presented a report on two schemes for the inner area; the first, for the treatment of all sewage and trade wastes on Motukorea Island; the second, for treatment of the sewage and trade wastes from the central area on Motukorea Island, and of sewage from the southern area at works located at a site adjoining the upper Manukau Harbor.

The construction cost is of the order of £3,500,000.

LANGDON PEARSE

Report to Auckland Metropolitan Drainage Board on Sewerage, Sewage Treatment and Sludge Disposal Schemes for the Inner Area of the Metropolitan Drainage Board's District. BY J. P. PORTER. 64 pp. (Dec. 15, 1948).

The Auckland Metropolitan Drainage Board was established in 1945, to provide an outfall system to an outer channel with treatment approved by the Harbour Board. The problem is complicated by industrial wastes and the choice of a method of sludge disposal. The present dry weather flow of sewage is around 45 Imp. g.c.p.d. (54.0 U.S. g.c.p.d.), from about 200,000 people. The present domestic dry weather flow is around 9 m.g.d. (Imp.), with an additional industrial flow of 2.5 to 4.5 m.g.d. (Imp.). The capacity of intercepting sewers and works should not exceed 5 times the D.W.F. The interceptors should be designed for 50 years ahead; the first section of treatment works for the next 15 years. In 2000 A.D. a population of 500,000 is expected.

The treatment required is:

1. Removal of grit and floating solids (retained on bar screen with 1-in. openings).
2. Reduction of suspended solids to 100 p.p.m.
3. Removal of grease, scum, and fat from surface of settling tanks.
4. Reduction of 5-day B.O.D. to 150 p.p.m. in dry weather for discharges of 15 Imp. m.g.d., and to 75 p.p.m. for discharges over 30 Imp. m.g.d.
5. Adjustment of pH to not less than 6.

Effluents complying with above will not be satisfactory if:

1. At 0.5 mi. from shore at ebb tide in channel the D.O. content of more than 2 samples in 10 is below 50 per cent of saturation,
2. *B. coli* of more than 2 samples in 10

is in excess of 100 per 100 cc., or any sample exceeds 500 per 100 cc.

Mr. Porter considers land disposal impractical. Ocean outfalls were previously rejected by others, because of excessive cost and possible disintegration of the outfall. All discharge, after suitable treatment, must go to either one or both harbors. Trade wastes materially increase the impurity load. Before works can be planned, industry must decide if it is to discharge into the system and pay for treatment. An alternative scheme was suggested for a hyacinth lake and the composting of the hyacinth, town, and industrial wastes with sewage sludge. The revenue would be very uncertain. The scheme is based on information of dubious theoretical value and no practical value. Consequently, it cannot be recommended to the Board. Composting of 70,000 tons of wet digested sludge annually also is held impractical.

Various established methods of sludge disposal are discussed. Digestion with sea disposal is held to be costly. Digestion may be followed by:

1. Sludge pressing, which is costly.
2. Elutriation, vacuum filtration, flash drying, and incineration, which require large amounts of fuel and chemicals and may be expensive in New Zealand.
3. Air drying, which is cheap to operate.
4. Air drying, followed by rapid drying at high temperatures. This is expected to sell at £6 to £10 per ton.

The last procedure is recommended in the hope that the value of gas produced, plus sale of fertilizer, will "almost equal the over-all cost of sludge disposal."

The cost of construction in New Zealand is at least twice as high in 1948 as in 1931; cost of imported equipment is 2½ times as great. The estimated cost of the project is around £3,500,000 ($9,800,000) with southern trade wastes, and £2,550,000 ($5,140,000) if southern trade wastes are excluded. The report is based on receiving trade wastes after minimum pretreatment, and that industrial establishments would contribute to the costs of construction and operation.

Mr. Porter concludes that:

1. It is inadvisable to locate the sewage treatment works for the inner area until it is known whether trade wastes arising in the Southern District are to be discharged into the Board's sewers or treated separately.

2. If trade wastes are to be permanently treated by the industries elsewhere, a suitable site is available on Motukorea Island for the sewage of the inner area.

3. If trade wastes are to be treated with the domestic sewage, the area available on Motukorea will suffice for the Central District only. Other works at Manzere or Southdown will be necessary, on other waterways.

4. The outfall from any works on Motukorea should discharge into Motukorea Channel, with provision for holding tanks to discharge effluents at ebb tide only.

5. That if works are located at Manzere or Southdown, the outfall should empty into the low-water channel, and an effluent holding tank provided to limit discharge to ebb tides only. If all sewage and trade wastes from the Southern District are treated at Motukorea, a high degree of oxidation is required.

Primary treatment will include medium screens, removal of grit and sand, and removal of grease, scum, and settleable solids.

Secondary treatment, if all the sewage and trade wastes are treated in a main plant will include: aeration and reactivation tanks for 11-hr. D.W.F.; final settling tanks, circular, with sludge scrapers; chlorination, if necessary, by a standby installation; and outfall works to discharge on all tides. An effluent holding tank can be cheaply built for 8-hr. D.W.F. to discharge purified effluent to Motukorea Channel on ebb tides only.

Heated sludge digestion, including primary tanks (15 days at 85° F.), with floating or fixed roofs, and open secondary tanks (25 days); sludge drying beds, about 15 acres; and a sludge pulverizing and bagging plant.

If mixed sewage and trade waste are to be treated in a separate southern plant the sewage may have a B.O.D. of 550 p.p.m., which may be treated by activated sludge (18-hr. aeration), after dilution of the settling tank effluent with purified effluent, or by the use of two-stage oxidation (roughing filters followed by activated sludge).

LANGDON PEARSE

Book Reviews

Chemical Engineers' Handbook. By John H. Perry. McGraw-Hill Book Company, New York 18, N. Y. Third Edition, 1950. 1,942 pp. Price, $15.00.

The third edition of this great standard reference work in its field has been fully revised and expanded to present the most authoritative, up-to-date information on the practice of chemical engineering. Progress in the theory and practice of chemical engineering, so greatly accelerated during prewar, war, and postwar years, has been so great that almost complete rewriting of most of the 30 major sections of the handbook has been necessary.

The revised edition appears in a new page size, enabling reduction in the book's thickness and permitting larger sizes of essential graphs and illustrations. A thoroughly revised and minutely cross-referenced index, as well as page-edge thumb tab delineation of the various sections of the books, makes for easier use of the content material. Several sections or chapters in previous editions have been deleted in the present edition in order to use the space for material believed to be more valuable in this handbook.

New sections added in this edition include: General Theory of Diffusional Operations; Furnaces and Kilns; Size Enlargement; Azeotropic Distillation; Multi-component Distillation; Extractive Distillation; Molecular Distillation; and Dialysis.

The following sections have been thoroughly revised: Flow of Fluids; Heat Transmission; Solvent Extraction; Mixing; Adsorption; Physical and Chemical Data; Physical and Chemical Principles; Mathematics; Mathematical Tables and Weights and Measures; Humidification, Dehumidification, Spray Ponds, and Cooling Towers; Fuels; Electrochemistry; Refrigeration; Electricity and Electrical Engineering; Materials of Construction; Mechanical Separations; Safety and Fire Protection; and Accounting and Cost Finding.

Sections that have been rewritten and expanded include: Size Reduction; Power Generation; Gas Absorption; Distillation; Plant Location; Drying; Movement and Storage of Materials; Process Control; and High Pressure Technique. In addition, the following chapters have been rewritten and expanded: Low-temperature Refrigeration and Processes; Miscellaneous Methods of Mechanical Separations; and Sublimation.

H. P. Orland

The Municipal Year Book, 1950. By Clarence E. Ridley and Orin F. Nolting, editors. International City Manager's Association, Chicago 37, Ill. June, 1950. 598 pp. Price $10.00.

The 17th annual volume of this authoritative resume of activities and statistical data of American cities brings into focus a vast amount of information through skillful summary of trends and developments in the various municipal activities. New sections in this volume include health department, library service, police, recreation, health, fire, and traffic safety data and analyses intended to guide municipal officials in determining the trend in quality and quantity of these services. Another new section shows individual city data on garbage collection and disposal practices in selected cities.

In addition, most of the regular features have been retained, although thoroughly revised to contain the latest available data. Of particular interest are the sources of information listed at the end of each section, as well as a valuable collection of selected model municipal ordinances covering all phases of municipal regulation. Salient points in the section on sewer service charges were covered in This Journal, **22**, 6, 775 (June, 1950).

H. P. Orland

Municipal and Rural Sanitation. By Victor M. Ehlers and Ernest W. Steel. McGraw-Hill Book Company, New York 18, N. Y. Fourth Edition, 1950. 548 pp. Price, $6.50.

In keeping with the excellent reputation established by former editions, the Fourth Edition of this well-known text and reference work deals with those fundamentals of general sanitation which should be familiar to engineers engaged in the sanitary and public health fields.

Basic information is given concerning the diseases eliminated by preventive sanitation. Sewage disposal and water supply are discussed from the point of view of operating problems, which leads to a discussion of subsequent solutions.

Among the recent advances included in the general coverage of the book are such topics as travel of contamination in ground water, control of typhus, DDT, diatomite water filters, "blue baby" condition resulting from excessive nitrates in water, and modern insecticides and disinfectant chemicals.

Comprehensive coverage is given by chapters on Communicable Diseases, Principles of Excreta Disposal, Excreta Disposal without Water Carriage, Excreta Disposal with Water Carriage, General Characteristics of Water, Treatment of Water, Protection of Water Supplies, Refuse Collection, Refuse Disposal, Mosquito Characteristics and Control Methods, Fly Control, Rodent Control, Milk Sanitation, Food Sanitation, Plumbing, Ventilation and Air Conditioning, Light, Housing, School Sanitation, Industrial Hygiene, Tourist Camps and Courts, Swimming Pool Sanitation, Disinfectants and Insecticides, Vital Statistics and Public Health Organizations.

An appendix gives the maximum allowable concentration values for continuous work-time exposure to various industrial poisons, including radioactive materials and radiations from radioactive materials and X-rays.

H. P. ORLAND

Rainfall and Runoff. By E. E. FOSTER. Macmillan Company, New York 11, N. Y. 487 pp. Price $9.00.

Called the first book to make use of the important material resulting from the multi-million dollar hydrologic studies of the last 15 or 20 years, this volume provides a clear, up-to-date exposition of the scientific principles and methods underlying all types of projects involving the control of water.

The practical approach has been emphasized in the analysis and solution of water control problems, with specific illustrations of the application of hydrologic principles. Major topics of interest to drainage designers and administrators are included in such chapters as Treatment of Hydrologic Data, Atmospheric Moisture and its Precipitation, Air Masses, Storms which Produce Precipitation, Distribution of Precipitation, Frequency of Precipitation, Snow, Runoff, Floods, and the Utilization of Hydrologic Data.

An excellent bibliography of 200 entries is included.

H. P. ORLAND

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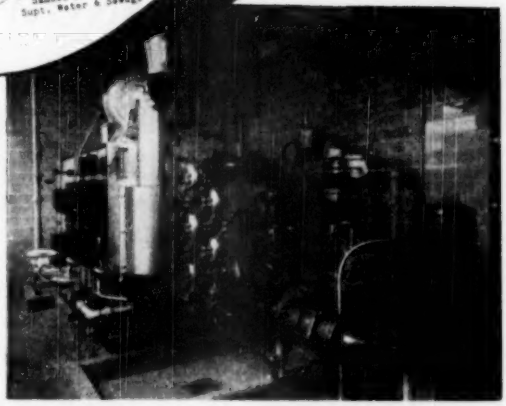
We feel that the pre-heater is operating beautifully, and justifies our efforts to have it installed.

With best wishes for the New Year, we are

Very truly yours,

Samuel H. Reaves
Supt. Water & Sewage



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Proceedings of Member Associations

MARYLAND-DELAWARE WATER AND SEWERAGE ASSOCIATION

The 23rd Annual Conference of the Maryland-Delaware Water and Sewerage Association was held at the Fort Cumberland Hotel, Cumberland, Md., on April 27–28, 1950. Registration for the meeting totaled 150 men and 15 ladies.

After an address of welcome by Mayor T. S. Post, of Cumberland, papers were presented, as follows:

"Birth Pains of the La Vale Sanitary District," by W. A. Douglas, chairman, La Vale Sanitary Comm.

"Proposed Sewage Treatment for Cumberland," by G. J. Requardt, consulting engineer, Baltimore, and Ralph L. Rizer, city engineer, Cumberland.

"Operation of Frederick Sewage Treatment Plant," by R. G. Hartmann, chief operator.

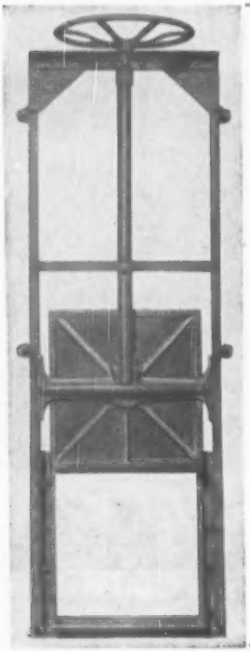
"Pollution Studies of Baltimore Harbor," by Chesley F. Garland, research associate, School of Engineering, Johns Hopkins University.

"Baltimore's Design of Small Sewers," by Bernard F. Suwall, Bureau of Sewers, Baltimore.

"Water and Sewerage for Consolidated School," by J. R. McComas, Maryland State Department of Health.

"Operators' Problems," by Ralph Fuhrman, superintendent, sewage treatment plant, District of Columbia.

(Continued on page 36)



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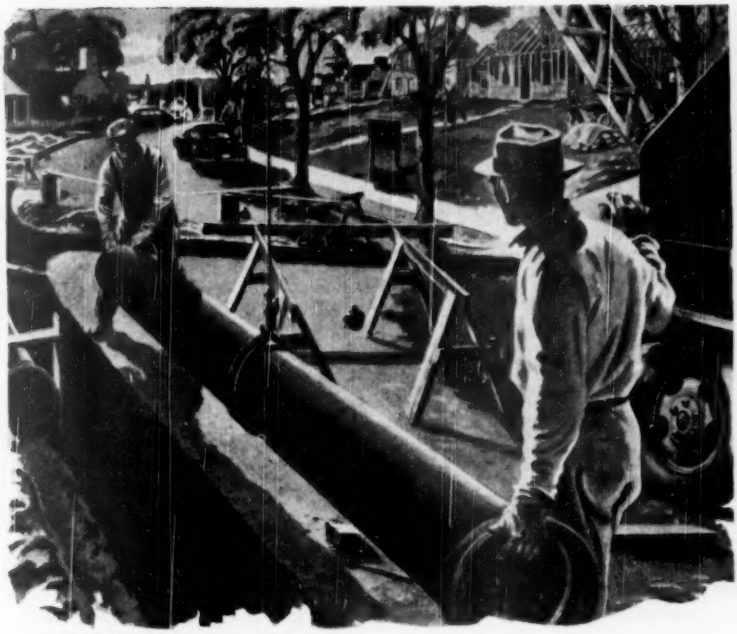

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At the business meeting the Association adopted constitutional amendments admitting to membership those engaged in refuse disposal and adjusting the annual dues to the new Federation charge for the Journal. The Association's nominee for the Federation's Arthur Sidney Bedell Award was announced as Abel Wolman, professor of sanitary engineering, Johns Hopkins University.

Officers elected for 1950–51 were:

President: R. E. Fuhrman, Washington, D. C.

1st Vice-President: L. E. McClung, Washington, D. C.

2nd Vice-President: V. W. Faivre.

Secretary-Treasurer: W. M. Bingley, Baltimore.

W. M. Bingley,
Secretary-Treasurer

CALIFORNIA SEWAGE WORKS ASSOCIATION

The California Sewage Works Association held is 22nd Annual Meeting at the Lafayette Hotel, Long Beach, Calif., May 3-6, 1950. A total of 275 persons registered for the convention, to set a new attendance record.

A "No Host" Dinner and Entertainment provided an enjoyable Dutch-treat get-together on the evening of May 3.

At the Operators' Breakfast on May 4, a paper on "Research on Waste Disposal Problems" was presented by V. W. Baker, research engineer, University of California. Meanwhile, at the concurrent Engineers' Breakfast, W. E. Elieson, deputy regional director, Bureau of Foreign and Domestic Commerce, U. S. Dept. of Commerce, presented a paper on "Construction Costs and Cost Trends in the United States."

The subsequent session comprised a "Symposium on Design, Construction, and Operation of Sewage Treatment

(Continued on page 38)

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See . . . the operating model of the *Dorr Type MA Digester* . . . a unit utilizing high-capacity mixing and gas storage for more effective operation where single stage digestion is applicable.

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In sewage treatment, there's a Dorr unit for practically every step in every flowsheet. You'll be able to see and discuss the latest developments at the Convention.

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THE DORR COMPANY, ENGINEERS
BARRY PLACE, STAMFORD, CONN.
NEW YORK • ATLANTA • TORONTO
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PETREE & DORR DIVISION, STAMFORD, CONN.
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Dorr Technical Services and Equipment Are Also Available Through Associated Companies and Representatives in the Principal Cities of the World. Names and Addresses on Request.

DORR

RESEARCH ENGINEERING EQUIPMENT

Plants," in which the State Board of Health viewpoint was presented by E. A. Reinke, chief, State Bureau of Sanitary Engineering; the engineer's viewpoint, by H. W. Jorgensen, consulting engineer, Los Angeles; and the operator's viewpoint, by F. Wayland Jones, superintendent, sewage treatment plant, Stockton.

The afternoon session was devoted to a panel discussion on industrial wastes, including the following papers:

"California's New Water Pollution Laws," by Frank M. Stead, executive director, California State Water Pollution Control Board.

"Waste Disposal at a Modern Brewery," by R. Schneider, brewmaster, General Brewing Corp., Azusa.

"Refinery and Oil Field Waste Disposal Problems," by W. Graham, supervisor of waste disposal, Richfield Oil Co., Wilmington.

"Suggested Methods for Handling Atomic Wastes in the Sewer System," by John Parkhurst, district engineer, Los Angeles County Sanitation District.

By courtesy of the Water and Sewage Works Manufacturers' Association, a Hospitality Hour was enjoyed by all on the evening of May 4.

On May 5, the morning session was devoted to a symposium on sewage reclamation, including:

"Need for Water Conservation in California," by G. B. Gleason, supervising hydraulic engineer, State Division of Water Resources.

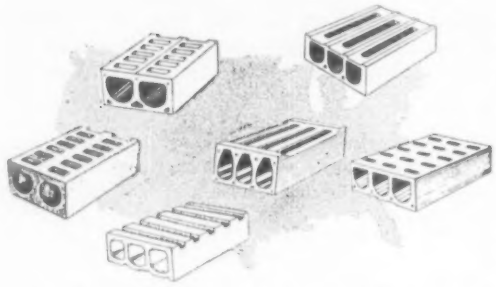
"Sewage Reclamation in Australia," by C. G. Hyde, consulting engineer, Berkeley.

"Sewage Reclamation in Fresno," by A. Segel, deputy commissioner of public works, Fresno.

At the business luncheon, W. H. Wisely, executive secretary, FSWA, spoke on "Public Relations from the

(Continued on page 40)

TODAY'S FILTER PLANTS use vitrified clay filter bottom blocks



In plant after plant today you find floors of *vitrified clay filter bottom blocks*—floors that give life-time, trouble-free service and the finest operating results. These blocks are scientifically designed to provide the right drainage and ventilation. Solids won't cling to their smooth channels. Air circulates freely through large top openings while the sewage flows out.

They are easy to lay, too, and self-aligning. You can work on them after laying. They come with standard fittings for all types and shapes of filters. Specify *vitrified clay filter bottom blocks* on your next job and forget about floor trouble.

Get full information today from any of our members below.

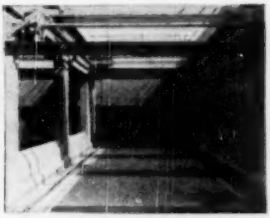
TRICKLING FILTER FLOOR INSTITUTE

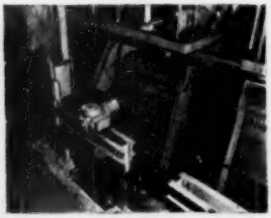
POMONA TERRA-COTTA CO., Pomona, N. Car. ● W. S. DICKEY CLAY MFG. CO., Kansas City 6, Mo.
BOWERSTON SHALE CO., Bowerston, Ohio ● AYER-McCAREL-REAGAN CLAY CO., Brazil, Ind.
TEXAS VITRIFIED PIPE CO., Mineral Wells, Tex. ● NATIONAL FIREPROOFING CORP., Pittsburgh 12, Pa.

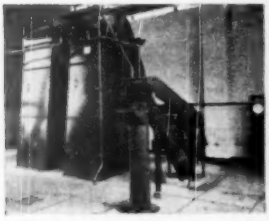
The treatment of water and sewage by mechanical means has definitely proved most effective and economical — is the accepted practice in practically all modern plants. Jeffrey Sanitation Engineers are Specialists— treat each case in a practical way — are qualified by experience to offer technical information on equipment and plant design. Send for list of Jeffrey-equipped plants now giving day-in and day-out service.

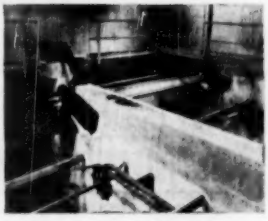
a treat to get right treatment

for instance









The five photos show the application of Jeffrey Screens, Collectors, Scum Removers and Grit Washers in both large and small plants. Also Sludge Elevators, Chemical Feeders, Screenings Grinders and equipment for biofiltration plants. Catalog No. 775-A goes into detail.

JEFFREY ESTABLISHED 1877 JM

SALES OFFICES IN PRINCIPAL CITIES

THE JEFFREY MANUFACTURING COMPANY • 902 NORTH FOURTH STREET, COLUMBUS, OHIO

Standpoint of the Sewage Works Operator." E. A. Reinke was named as the Association's nominee for the Federation's Arthur Sidney Bedell Award.

Officers elected to serve for 1950–51 were:

President: F. G. Nelson, Los Angeles.
1st Vice-President: H. B. Gotaas, Berkeley.
2nd Vice-President: A. G. Pickett, San Marino.
Secretary-Treasurer: L. H. Cook, Menlo Park.

The remainder of the afternoon was devoted to papers, as follows:

"Subsidence at Long Beach," by C. L. Vickers, assistant engineer, Long Beach Harbor Dept.

"Use of Trucks and Tools in Sewer Maintenance," a colored sound film by the City of Los Angeles.

"Sewage Characteristics," by J. T. Norgaard, consulting engineer, Oakland.

"Considerations in the Selection of Engines for Operation on Sewage Sludge Gas," by H. Hayes, professor of mechanical engineering, Santa Clara University.

"Elutriation at Richmond Sunset Plant, San Francisco," by K. Fraschina, superintendent.

This was followed in the evening by the Annual Banquet, Entertainment, and Dance, for which A. W. Miller, of Phoenix, Ariz., acted as master of ceremonies.

The final day, May 6, was occupied by an inspection trip to the new Los Angeles plant at Hyperion.

L. H. Cook,
Secretary-Treasurer

PACIFIC NORTHWEST SEWAGE WORKS ASSOCIATION

At the 17th Annual Meeting of the Pacific Northwest Sewage Works As-

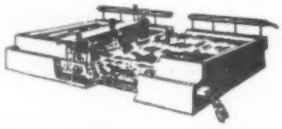
(Continued on page 42)

"Don't Jump!
There's Still Hope!
Try the **HARDINGE AUTOMATIC BACKWASH SAND FILTER!"**

The Hardinge Automatic Backwash Rapid Sand Filter cleans its own filter bed automatically, during operation. It runs at peak efficiency at all times without shutdown or change-over. It is extremely efficient in removing fine suspended matter not separable by sedimentation.

One 12' x 88' installation, handling 2200 gallons per minute of municipal water, reduced solids from 8.09 p.p.m. to 0.06 p.p.m.—99% removal.

Another 12' x 40' filter handling 750,000 gallons per day of paper mill "white water" reduced the suspended solids from 195 p.p.m. to 21.1 p.p.m. or 89% removal.



Look for the HARDINGE EXHIBIT in Booths 49 & 50 at the F.S.W.A. Convention, Washington, D.C., October 9-12

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COMPANY INCORPORATED
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NEW YORK 17—122 E. 42nd St. · 205 W. Wacker Drive—CHICAGO 6
SAN FRANCISCO 11—24 California St. · 200 Bay St.—TORONTO 1

Write for Bulletin 46-16

Less Infiltration

TRANSITE* SEWER PIPE offers two basic safeguards that minimize infiltration in sewer lines: *tighter* joints and *fewer* joints.

Transite's special sleeve-type joints make up tight and stay tight in service.

Its long 13-foot lengths reduce the number of joints in the system.

These safeguards cut down the volume usually allowed for infiltration, reducing sewage load on the treatment plant and conserving plant capacity for future needs. Where new treatment facilities are planned, this reduced infiltration may permit consideration of a smaller plant with resulting economies.

Other Transite Economies—Transite's long lengths help maintain uniform grades; fewer joints reduce turbulence in the line. These advantages, added to Transite's unusually smooth interior, mean better flow qualities (Kutter's N=.010). This often permits designing the system with flatter grades and shallower trenches. Or, as an alternate economy, pipe of smaller diameter may be specified.

Transite Sewer Pipe is made of asbestos, cement and silica by a special manufacturing process that employs steam curing to develop greater corrosion resistance and strength. It is available in four strength classes in sizes to 36", permitting selection of the pipe best suited to trench conditions, and frequently eliminating the need for concrete cradles.

For further details, write Johns-Manville, Box 290, New York 16, N. Y.

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TRANSITE SEWER PIPE . . .

THE RATHBUN-JONES
ENGINEERING CO., TOLEDO, OHIO
MANUFACTURERS OF
DIESEL ENGINES, GAS & DUAL FUEL ENGINES

sociation, held at the Hotel Winthrop, Tacoma, Wash., May 10–11, 1950, a new attendance record was established, with 182 persons registered.

The technical session on May 10, after an address of welcome by Mayor C. V. Fawcett, of Tacoma, heard a paper on "Effects of Industrial Wastes in Municipal Sewerage Works and Their Control," by E. F. Eldridge, director and chief engineer, State Pollution Control Commission, Olympia, Wash. This was followed by a panel discussion on "Digester Operation Problems," in which the participants were D. Livingston, consulting engineer, Seattle, Wash.; F. E. Mathews, superintendent, sewage treatment plant, Ellensburg, Wash.; F. M. Emery, city engineer, Seattle, Wash.; and J. Ingalls, superintendent, sewage treatment plant, Coeur d'Alene, Idaho. R. E. Leaver, engineer, State Dept. of Health, Seattle, Wash., then presented a paper on "The Practical Values of Operation Reports."

At the Annual Luncheon, D. E. Morris told of Tacoma's sewerage problems and plans for their correction.

With the exception of progress reports on the Federal stream pollution control program and the Association's investigation of operator short schools and certification, the afternoon session was devoted entirely to a panel discussion on "Problems of Sewer Line Construction." Panel members and the subjects covered were as follows:

"Trench Widths and Depths: ASTM Pipe," by G. Ingram, Seattle, Wash.

"Bedding, Backfilling, and Foundations," by J. W. Cunningham, consulting engineer, Portland, Ore.

"Joints and Jointing Materials with Regard to Infiltration," by R. Koon, consulting engineer, Portland, Ore., and W. P. McNamara, engineer, City Engineering Department, Seattle, Wash.

"Inspection, Including Field and

(Continued on page 44)

SEWER AND PIPE CLEANING EQUIPMENT
Sewer Rods, Wood & Steel Root Cutters, Buckets
Sewer Machines, Engine Driven & Hand Operated
Steel Tapes, Flushers, Nozzles & Brushes
Send for complete catalog
W. H. STEWART, INC.
P.O. Box 767 Syracuse, N. Y.

Consulting Engineer Haskins Specifies Inertol Paints throughout two new sewage plants

North Side Sewage Plant, the larger of the two plants at Joplin, Missouri.
Inertol colors and black bituminous paints applied throughout both plants.
Consulting Engineer: Charles H. Haskins, Kansas City.
Contractor for North Side Plant: Eby Construction Company, Wichita.
Contractor for South Side Plant: Lippert Brothers, Oklahoma City.

Stringent paint specifications for both Joplin plants

Exterior steel and equipment exposed to fumes: "Rustinhibitive Primer and Ramuc Utility Enamel as manufactured by Inertol Co., Inc. or approved equal." Exposed interior piping: "Rustinhibitive Primer and . . . a tough high-gloss protective enamel similar and fully equal to Inertol Glamortex." Concrete ceilings, upper walls, dadoes, floors: "Ramuc Utility Enamel or approved equal." Concrete and steel submerged in sewage: "approved acid-resistant paint similar and fully equal to Inertol Standard and Inertol Standard Thick respectively."

For exposed surfaces, the engineer chose the colors Battleship Grey, Dark Green, White and Medium Grey. For submerged surfaces, Black.

Why specify Inertol coatings?

Specify Inertol to satisfy clients and eliminate complaints on the paint job. Since Inertol chemists employ tough, chemical-resistant resins and pigments, the finished coatings stand up to abrasion, fumes, condensation and submersion. No peeling, no blistering, no fading. Inertol paints enduringly beautify and protect sewage plants.

Local Inertol representatives for your convenience

Drop a post card to Inertol: "Have your local man see me about painting specifications."

INERTOL CO., INC.

19 South Park
San Francisco 7, California

480 Frelinghuysen Avenue
Newark 5, New Jersey

Inertol, Ramuc, Glamortex—Trademarks registered U. S. Pat. Off.

Plant Tests," by C. S. Seabrook, Tacoma.

"Responsibility for Compliance with Specifications," by J. Morrison, Ellensburg, Wash.

The speaker at the Annual Dinner Meeting was W. H. Wisely, who entertainingly told of the multitudinous functions and services performed by the Federation office in the members' behalf.

The May 11 session opened with an Operators' Breakfast held jointly with the Pacific Northwest Section, AWWA. This was followed by a Sewage Works Operators' Forum, after which another joint session with the AWWA section was devoted to public relations discussions.

Informal inspection tours of the manufacturing and waste treatment facilities of the Hooker Electrochemical Co. and the Pennsylvania Salt Manufacturing Co. plants occupied the afternoon of May 11.

Officers elected for 1950–51 were:

President: W. P. McNamara, Seattle, Wash.

1st Vice-President: W. W. Tinniswood, Moscow, Idaho.

2nd Vice-President: C. M. Everts, Jr., Portland, Ore.

FSWA Director: W. P. Hughes, Lewiston, Idaho.

Secretary-Treasurer: R. E. Leaver, Seattle, Wash.

R. E. LEAVER,
Secretary-Treasurer

MICHIGAN SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 25th Annual Conference of the Michigan Sewage Works Association was held at the Park Place Hotel, Traverse City, Mich., May 22–24, 1950. A new all-time Association attendance

(*Continued on page 46*)

Vitrified salt-glazed Clay Pipe

RESISTS WEAR AND ABRASION

Vitrification at the metal-melting heat of 2200° F welds the particles of clay into a dense, hard, strong unit. Fast-moving particles of grit in sewage can't harm vitrified clay.

RETAINS HIGH CARRYING CAPACITY

A bright salt-glaze marks the finest pipe. Its glossy surface is hard, smooth, sanitary, and *stays that way*. There is no roughness to catch clogging silt. Flow friction is lowered.

PROOF AGAINST CHEMICAL FAILURE

By its nature, clay is chemically inert. It cannot unite with the acids and alkalis of sewage, no matter how strong they are. It cannot rust or rot. It has the endurance of the earth itself.

For enduring sewers, specify salt-glazed, vitrified clay pipe.

CLAY PRODUCTS ASSOCIATION

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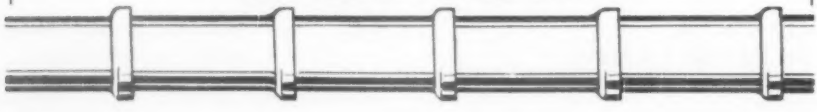


SEND FOR MANUAL 149—MODERN PROCESSES AND EQUIPMENT FOR SEWAGE AND INDUSTRIAL WASTE TREATMENT

BIO-ACTIVATION—exclusive system combines best qualities of trickling filter and activated sludge. *Bulletin 259A.*

MECHANICALLY CLEANED SCREENS—with intermittent automatic control. *Technical Supplement-MS*-Complete Design Data.

GRIT CHANNELS—exclusive Camp Chamber design and Regulator permit easy and instant variations in velocity. *Technical Supplement-CR*-Complete Design Data.

GRIT SETTLERS—with conveyor and exclusive Hydrowash unit which removes grease and organic matter from grit. *Bulletin 249.*

GREASE FLOTATION UNIT—removes grease and oils, oxidizes odors, and aerates by exclusive pretreatment method. *Bulletin 260A.*

SLUDGE COLLECTORS—for rectangular and circular tanks . . . flight type and helicoid cross conveyors, sludge valves. *Bulletin 253A.*

AERATORS—downflow mechanical air diffusion type provides thorough and adjustable oxygenation and circulation of liquor. *Bulletin 265.*

JET AERATION—exclusive method produces an unprecedented rate of oxygen absorption. *Technical data available.*

ROTARY DISTRIBUTORS—reaction and positive drive types with exclusive trouble-free oil seal. *Bulletin 257.*

DOWNFLO FLOCCULATION UNIT—for slow mixing and flocculation of chemicals in sewage treatment processes. *Bulletin 266.*

Send for instructive bulletins listed above

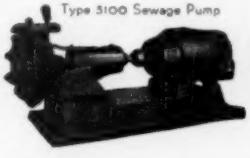
COMPLETE LINE . . .

Including many Exclusive Developments

Many years of close collaboration in the engineering of municipal and industrial waste treatment plants have enabled us to develop a complete line of installation-tested equipment. Our staff of Sanitary Engineers is exceptionally well qualified to cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

SEWAGE AND SLUDGE PUMPS

American sewage and sludge pumps are unusually strong and rugged in construction. Generous shaft diameter, sturdy bearings, proper bearing span, finest materials, extra metal, careful inspection and testing. *Send for Bulletins.*


Type 3100 Sewage Pump

See Our Exhibit, Booths 19–20–21
Annual Meeting Federation of Sewage Works Associations
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Pumping, Sewage Treatment, and Water Purification Equipment
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record was established with 204 registrations.

The first technical session, held on the afternoon of May 22, was of general interest to all. It included a discussion of "America's Water Wonderland," by John Gray, publicity director, Michigan Tourist Council, Lansing; "Keys to Successful Sewerage Services," by J. M. Hepler, director, Division of Engineering, Michigan Department of Health; and "The Mount Clemens Sewage Project," by T. B. Henry, consulting engineer, Toledo, Ohio.

In the evening, the Annual Smoker, with entertainment and refreshments furnished by the Water and Sewage Works Manufacturers' Association, provided a splendid opportunity for fellowship and enjoyment.

Concurrent sessions on the morning of May 23 stressed primarily sewage affairs and industrial waste matters. Papers given at the sewage session were:

"Landel Metropolitan District—The Answer to Urban Community Sanitary Problems," by D. W. Granger, engineer, Landel Metropolitan District, Lansing.

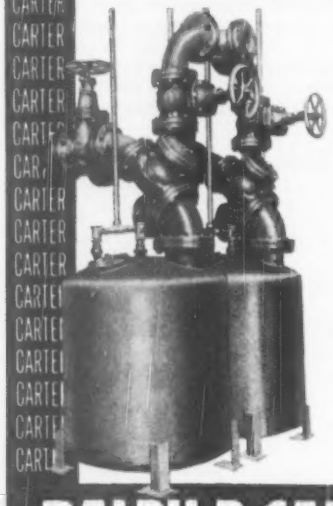
"Accident Control in Sewage Treatment," by Wendell R. Williams, supervisor, Employers' Group, Michigan Engineering Dept.

The industrial wastes session was devoted to panel discussions on "Water Pollution Indices and Limitations" and "Review on Biological Treatment." Panel members for the first subject were L. F. Oeming, chief engineer, Michigan Water Resources Commission; S. Mogelnicki, research and development engineer, Dow Chemical Co., Midland; and J. E. Cooper, supervisor, Special and Sanitary Engineering Section, Ford Motor Co., Dearborn. Panel members for the second subject were: R. Purdy, sanitary engineer, Michigan Water Re-

(Continued on page 48)

CARTER'S PNEUMATIC SEWAGE EJECTOR

for continuous, trouble-free, economical handling of sewage lift problems



For day-in-and-day-out 100% sewage boosting you can't afford *not* to consider Carter's pneumatic sewage ejectors. They practically pay for themselves by elimination of the costly auxiliary screening equipment required with centrifugal pumps.

Solids and trash up to the size of the inlet and discharge valves are easily handled. No moving parts—no clogging or binding. Pots are either copper bearing, electrically-welded steel or cast iron—to your specifications. Hermetically sealed—completely eliminate stuffing box leaks and toxic gas dangers. Bronze mounted double disc gates and swing check valves. Rotary type air compressors of high volumetric efficiency. Fully automatic controls. Capacities—30 to 300 GPM.

Write Dept. S—give your specific waste problems, and we'll promptly furnish a detailed reply.

ROTARY DISTRIBUTORS • FLOATING & FIXED COVER DIGESTERS • ALTERNATING SIPHONS • PADDLE AERATORS • SLUDGE PUMPS • RAPID & SLOW MIXERS • PNEUMATIC EJECTORS • CIRCULAR COLLECTORS • FLOCCULATION EQUIPMENT • DIAPHRAGM PUMPS • SELF-PRIMING CENTRIFUGAL PUMPS • PLUNGER PRESSURE PUMPS

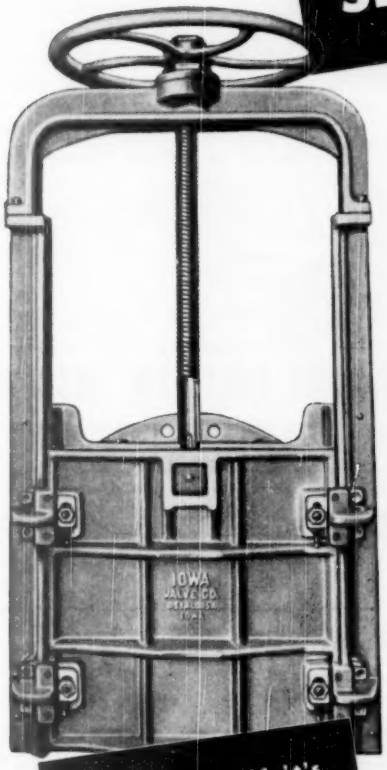
Exclusive franchises for representatives still open in some select territories. Write today!

184 Atlantic Street, Hackensack, N. J.

RALPH B. CARTER CO. HACKENSACK, NEW JERSEY

7 Reasons Why

IOWA SLUICE GATES



Remember — if it's Sluice Gates you need . . . specify IOWA

Meet the Most Rigid Service Requirements in Sewage Disposal Plants

1 Gates are ruggedly built of cast iron . . . sturdily reinforced with sectional ribs and fully bronze mounted.

2 Stem and stem nut are of heavy bronze construction.

3 Non-rising stem self-contained or rising stem types, with solid bronze adjustable wedges, suitable for seating or unseating pressures.

4 Furnished with flanged or flanged and spigot ends, or with flat frame for bolting directly to concrete wall.

5 Can be operated manually or equipped with cylinder or motor unit for hydraulic or electrical operation.

6 Made in sizes 4" to 24" inclusive with either circular or square opening.

7 Quality built throughout for hard usage and long life.

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sources Commission; C. Fiske, chief control chemist, Leonard Refineries, Inc., Alma; J. J. Nieboer, waste treatment plant operator, Mead Johnson & Co., Zeeland; and A. J. Palladino, National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries).

Concurrent sewage and industrial wastes sessions were also held on the afternoon of May 23. The former was devoted to maintenance practices in sewage treatment plants, with the following panel members discussing the phases indicated: C. W. Brandell, field engineer, Wallace and Tiernan Co., chlorinators; W. S. Mullen, district engineer, Morris Machine Works, pumps; R. W. Clark, sales engineer, Brown Instrument Division, meters; L. E. Langdon, Pacific Flush Tank Co., sludge and gas equipment; and L. Bancroft, superintendent of parks, Lansing, landscaping.

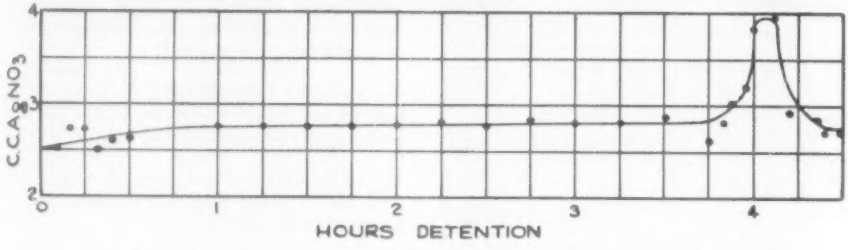
The industrial wastes group heard papers on "The Relationship of the State Health Department to Industrial Wastes," by D. M. Pierce, sanitary engineer, Michigan Department of Health, and "Industrial Waste Control Progress Report," by L. N. Rydland, sanitary engineer, Michigan Water Resources Commission, and S. C. Martin, senior sanitary engineer, U.S. P.H.S., Chicago, Ill. In addition, intense interest was centered on two symposia:

"Chemical Treatment of Industrial Wastes," by D. Milne, chemical engineer, General Motors Corp.; C. W. Waite, chief chemist, King-Seeley Corp.; and J. Teal, chemist, Dow Chemical Co.

"Waste Acid Neutralization," by J. E. Cooper, supervisor, Special and Sanitary Engineering Section, Ford Motor Co.; I. Nusbaum, civil engineer, City Engineer's Office, Detroit; and D. Miller, chemist, Sharples Chemicals, Inc., Wyandotte.

(Continued on page 50)

SPIRAFLO SETTLING TANKS PRODUCE EXCELLENT RESULTS



This salt detention curve was obtained from a 39 ft. dia. by 9 ft. S.W.D. primary Spiraflo, when the theoretical detention in the tank amounted to 5.3 hrs. Depth of Spiraflo skirt 7'-4".

Plant No.	*% Removals by Spiraflo*		*% Removals by entire Plant*		*Duration of Test*
	B.O.D.	*S.S.*	*B.O.D.*	*S.S.*	
1	56.0	—	—	—	4 mos.
2	47.8	70.	91.7	90.6	8 days
*3	40.7	54.7	—	—	8 days
4	57.0	—	92.0	—	24 hrs.
**5	55.65	74.6	94.4	91.0	4 mos.
6	—	—	96.0	—	24 hrs.
7	65.0	76.0	—	—	6 days

* Heavy proportion of non-settleable trade wastes.
** Two-stage Spiraflo with Aero-filter.

LAKESIDE ENGINEERING CORPORATION · CHICAGO, ILL.

See
General American for
CREATIVE
FILTER
ENGINEERING

For better filtration at lower cost... municipalities and industries specify Conkey Sludge Filters

Designed to do your job best!

What's your sludge dewatering problem—primary directly handled *or* digested *or* digested and elutriated, activated with the same handling, chemical treatment or special process, *or* is it a trade waste? No matter what its specific nature, Conkey Sludge Filters are engineered, built and installed to do the job better, more economically.

Rapid, continuous, automatic sewage sludge dewatering is the aim of all progressive sanitary engineers. Conkey filters with their superior drainage design, their improved mechanical construction, and their advance selection of materials of fabrication fulfill these aims in the most perfect manner.

The Sanitary District of Chicago, and the sewage engineers of many other cities have selected Conkey Sludge Filters for their new plants. Your engineering files should contain a copy of our Bulletin No. 100 that gives more complete information. Write for it now.

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The industrial waste session was concluded by a panel discussion on "The Effect of Increased Activity in Air Pollution Control on the Problem of Stream Pollution."

The Annual Banquet was held on May 23. W. J. Hale, consulting chemist, Dow Chemical Co., spoke on "The Chemurgic Age at Last." Club room entertainment preceding the banquet was furnished by the Water and Sewage Works Manufacturers' Association.

Papers presented at the May 24 sessions were:

"Use and Application of Protective Coatings in Industrial Wastes and Sewage Treatment Plants," by W. J. Sandel, Amercoat Corp., Chicago.

"Municipal and Industrial Cooperation in Solving Waste Disposal Problems," by L. F. Warrick, chief, Technical Services Branch, Division of Water Pollution Control, U.S.P.H.S.

"Federal Loans for Planning Community Facilities," by D. M. Hatch, district engineer, Community Facilities Service, Detroit.

"Ground Water Pollution by Industrial Wastes in Michigan," by N. Billings, hydrogeologist, Geological Survey Division, Michigan Dept. of Conservation.

"The Role of the Stream in the Waste Treatment Process," by C. J. Velz, professor of public health statistics, University of Michigan.

At the Annual Business Meeting, the Association overwhelmingly voted to change the name to Michigan Sewage and Industrial Wastes Association.

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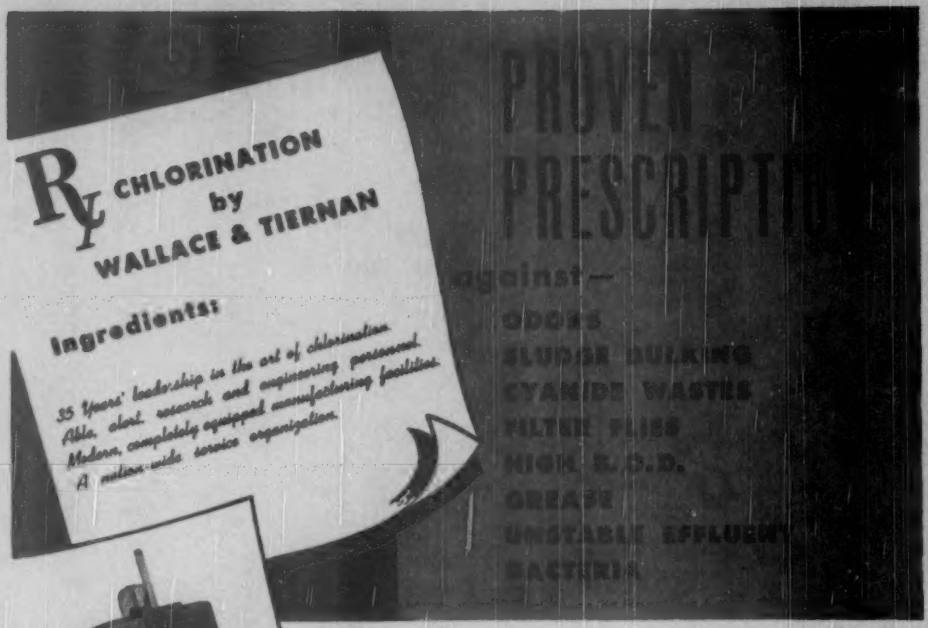

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